八十五學年度 化學工程學系 系（所） 甲組 組碩士班研究生入學考試

科目 輸送現象及單元操作 科號 1501 共 5 頁第 1 頁 *請在試卷【答案卷】內作答

Problem 1(20%)

(a) Give an example in which the no-slip boundary condition is inapplicable. (4%)

(b) What is the similarity between the following three physical properties: kinematic viscosity, thermal diffusivity, and diffusion coefficient? (4%)

(c) For a given physical quantity, for example velocity, temperature, or species concentration, if its distribution is in a steady state, then which of the following time derivatives of the physical quantity is zero? Partial time derivative, total time derivative, or substantial time derivative? Why? (3%)

(d) Give the physical meaning of the boundary condition $\partial T / \partial x = 0$. Note: don't just say the temperature gradient in the x direction is zero ! (3%)

(e) Give a situation in which the concentration of species i can be set as zero on a boundary. Also give a situation in which the concentration derivative of species i can be set as zero on a boundary. (6%)

Problem 2 (20%)

To examine the viscous heating in a co-rotational cylinders system as shown in Figure A, we may assume that the flow between the two cylinders is close to the flow between two parallel planes as shown in Figure B.

(i) Under what condition(s) may we assume that the two-parallel planes system is valid (2%)

(ii) A cartesian system is introduced to the system in Figure B. The equations of motion and energy are as follows:

$$0 = \frac{d}{dy}\left(\eta \frac{dv_x}{dy}\right) \qquad (1)$$

$$0 = \frac{d}{dy}\left(K \frac{dT}{dy}\right) + \eta\left(\frac{dv_x}{dy}\right)^2 \qquad (2)$$

here v_x is the velocity component in the x-direction, T is the fluid temperature, η is the fluid viscosity which has the following form

$$\eta = m\left(\frac{dv_x}{dy}\right)^{n-1}$$

where m and n are constants. The thermal conductivity K is also constant.

List the assumption necessary so that equations (1) and (2) are valid. (5%)

(iii) Define the following dimensionless variable

$$\phi = \frac{v_x}{V}, H = \frac{(T - T_0)}{\Delta T_0}, \xi = \frac{y}{R(1-\varepsilon)}$$

$$\Delta T_0 = mV^{n+1}/[R(1-\varepsilon)]^{n-1}K$$

Derive the dimensionless form of equations (1) and (2), also write down the corresponding dimensionless boundary conditions. (5%)

(iv) Solve the dimensionless equations to find ϕ and H. (5%)

(v) Determine the maximum temperature in the system and its location . (3%)

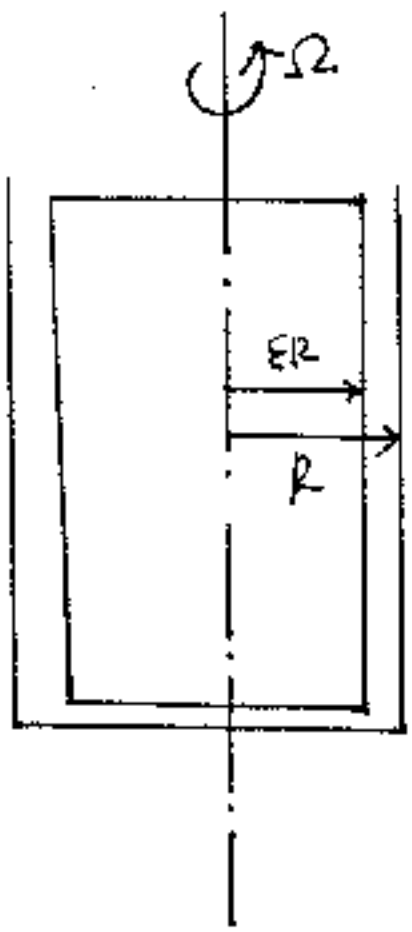

Figure A

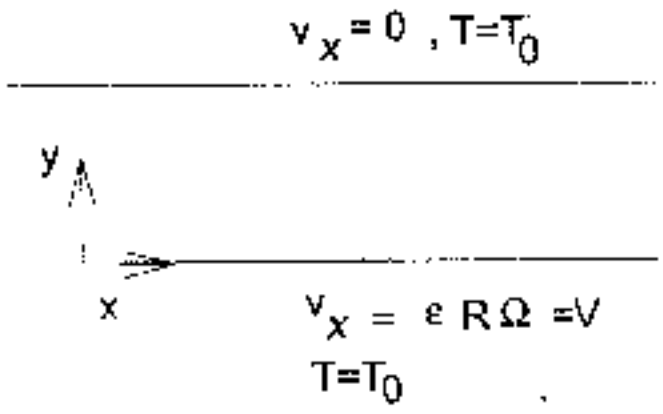

Figure B

Problem 3 (20%)

A coaxial-tube counterflow heat exchanger is to cool 0.035 kg/s of benzene from 360K to 310K with a counterflow of 0.02 kg/s of water at 280K. If the inner tube outside diameter is 2 cm, and the overall heat transfer coefficient based on outside area is 750 W/m^2-K, (1) determine the required length of the exchanger. The specific heats of benzene and water are 1880 and 4175 J/kg-K, respectively. (2) If the two flows are in the same direction, i.e., cocurrent flow, what would be the length of exchanger, if all the other properties are unchanged?

Problem 4 (20%)

A feed containing 200 mol/h of an n-heptane (40 mol%)+ethylbenzene (60 mol%) mixture is to be fractionated at 101.3 kPa to give a distillate containing 97 mol% of n-heptane and a bottom containing 1 mol% of n-heptane.

(a) (5%) Calculate flow rates of the distillate and the bottom.

(b) (5%) Calculate the minimum number of theoretical plates and minimum reflux ratio required if the feed is a saturated liquid.

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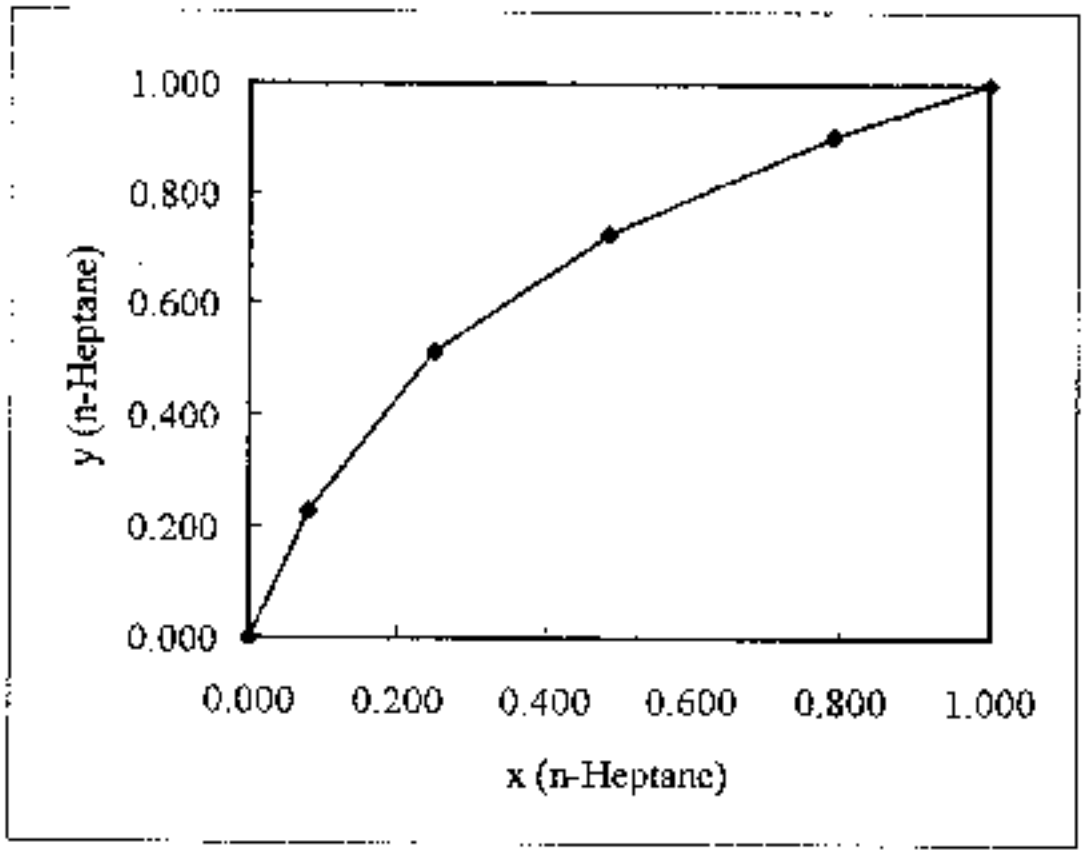
(c) (5%) Calculate the number of theoretical plates required at a reflux ratio of 2.5:1 if the feed is a saturated liquid.

(d) (5%) If a distillation column is designed based on results of (c), but in actual operation , 20% of feed is vaporized, what will be the required reflux ratio to accomplish the same separation.

The following is a y-x diagram of n-heptane+ethylbenzene at 101.3 kPa. If you do not have time to obtain accurate results, you can explain the method used with sketch diagrams.



Problem 5 (20%)

(a) Consider a one-dimensional mass diffusion of species A through a planar medium of A and B, as shown in figure (a). For steady state conditions with no homogeneous chemical reactions, find the concentration distribution of component A in the planar medium $(0 \le x \le L)$ where $x_{A1} < x_{A2}$.

(b) Consider a one-dimensional mass diffusion of species A through a cylinder medium of A and B as shown in figure (b). For steady state conditions with no homogeneous chemical reactions, find the concentration distribution of component A in the cylinder medium $(r_1 \le r \le r_2)$ where $x_{A1} < x_{A2}$.

(c) Consider a one-dimensional mass diffusion of species A through a sphere medium of A and B as shown in figure (c). For steady state conditions with no homogeneous chemical reactions, find the concentration distribution of component A in the sphere medium ($r_1 \le r \le r_2$) where $x_{A1} < x_{A2}$.

(d) Consider a one-dimensional mass diffusion of species A through a sphere medium of A and B as shown in figure (c). For steady state conditions with homogeneous chemical reaction (reaction rate, $r = kx_A$), find the concentration distribution of component A in the sphere medium ($r_1 \le r \le r_2$) where $x_{A1} < x_{A2}$.

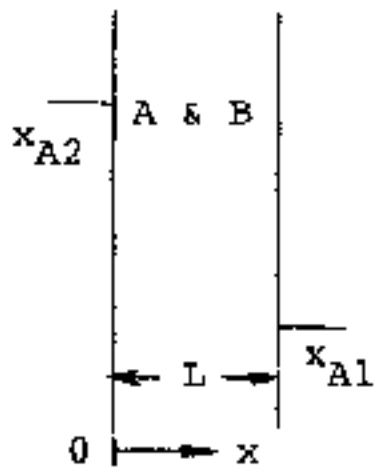


Fig. (a)

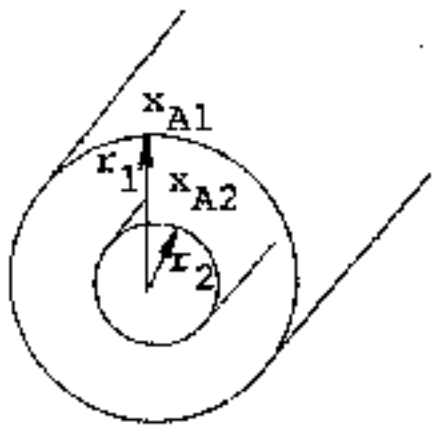


Fig. (b)

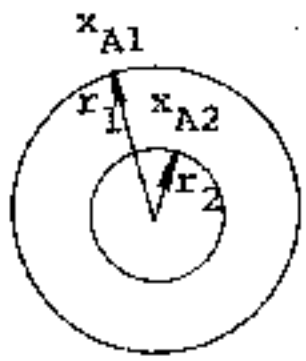


Fig. (c)