國立清華大學 102 學年度碩士班考試入學試題

系所班組別：化學工程學系

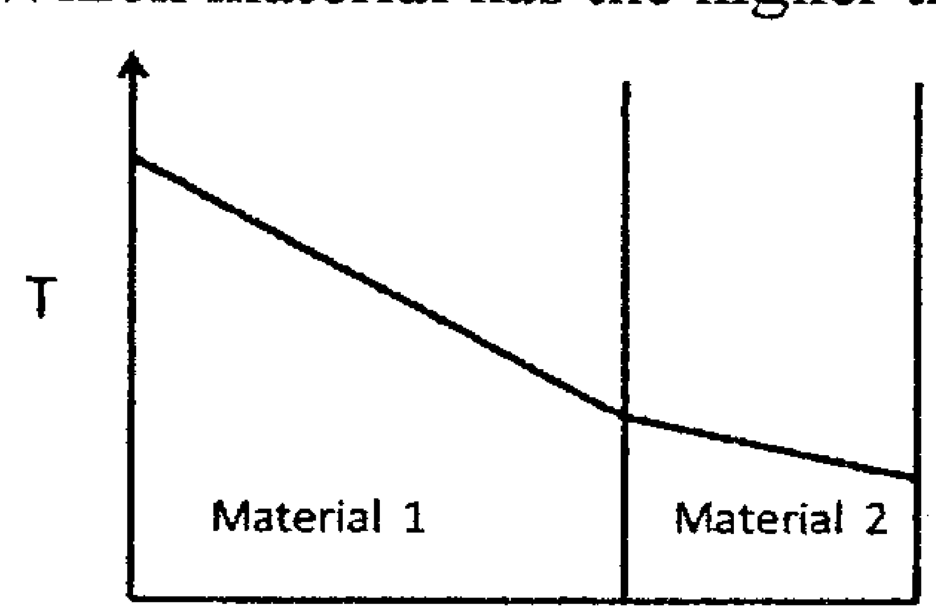
考試科目（代碼）：輸送現象及單元操作(0901)

 *請在【答案卡】作答

一、選擇題 20 題(每題 2 分，不倒扣，請於電腦卡作答，違者不計分)

Multiple choice: (Pick only one answer for each problem.)

1. What is the SI unit of thermal diffusivity?
   (A) W/(m K), (B) m^2/s, (C) W/(cm K), (D) cm^2/s.
2. What is the SI unit of Prandtl number?
   (A) 1/m, (B) W, (C) J, (D) dimensionless.
3. For the following materials, (a) brick at 273 K, (b) brick at 373 K, (c) Cu at 273 K, and (d) Cu at 373 K, place them in the order of increasing thermal conductivity.
   (A) (b)(a)(d)(c), (B) (b)(a)(c)(d), (C) (a)(b)(d)(c), (D) (a)(b)(c)(d).
4. For the following fluids, (a) SAE 50 oil at 300 K, (b) SAE 50 oil at 400 K, (c) air at 300 K, and (d) mercury at 500 K, place them in the order of increasing Prandtl number.
   (A) (a)(b)(c)(d), (B) (d)(c)(b)(a), (C) (c)(a)(b)(d), (D) (d)(c)(a)(b).
5. Consider an electric wire of radius R. The electric current generates heat at a rate per unit volume of Se. The surface of the wire is maintained at temperature T_0. What is the rate of outflow heat at the wire surface (for a length of L) at steady state?
   (A) $(T_{max}/T_0)\pi R^2 LSe$, (B) $(T_0/T_{max})\pi R^2 LSe$, (C) $\pi R^2 LSe$, (D) $2\pi RLSe$.
6. Consider the viscous heating of a Newtonian fluid of constant density and viscosity, flowing between two large plates separated by a distance b. The temperature of the lower plate (located at x=0) is maintained at T_0 and that of the upper plate at T_b (located at x=b). What is the temperature distribution in the fluid domain? (Br is the Brinkman number.)
   (A) $\left(\frac{T-T_0}{T_b-T_0}\right)=\frac{1}{2}Br\frac{x}{b}\left(1-\frac{x}{b}\right)+\frac{x}{b}$, (B) $\left(\frac{T-T_0}{T_b-T_0}\right)=\frac{1}{2}\frac{x}{b}\left(1-\frac{x}{b}\right)+Br\frac{x}{b}$,
   (C) $\left(\frac{T-T_0}{T_b}\right)=\frac{1}{2}Br\frac{x}{b}\left(1-\frac{x}{b}\right)+\frac{x}{b}$, (D) $\left(\frac{T-T_0}{T_b}\right)=\frac{1}{2}\frac{x}{b}\left(1-\frac{x}{b}\right)+Br\frac{x}{b}$.
7. Consider the following steady state temperature profile in a laminated system. Which material has the higher thermal conductivity?



   (A) Material 1, (B) material 2, (C) they are equal, (D) cannot be judged.

8. The equation of change for temperature in terms of the heat flux vector, $\underline{q}$, and the viscous momentum flux tensor, $\underline{\underline{\tau}}$, is given as the following.

$$\rho \hat{C}_p \frac{DT}{Dt} = -\underline{\nabla} \cdot \underline{q} - \underline{\underline{\tau}} : \underline{\nabla v} - \left(\frac{\partial \ln \rho}{\partial \ln T}\right)_p \frac{Dp}{Dt},$$

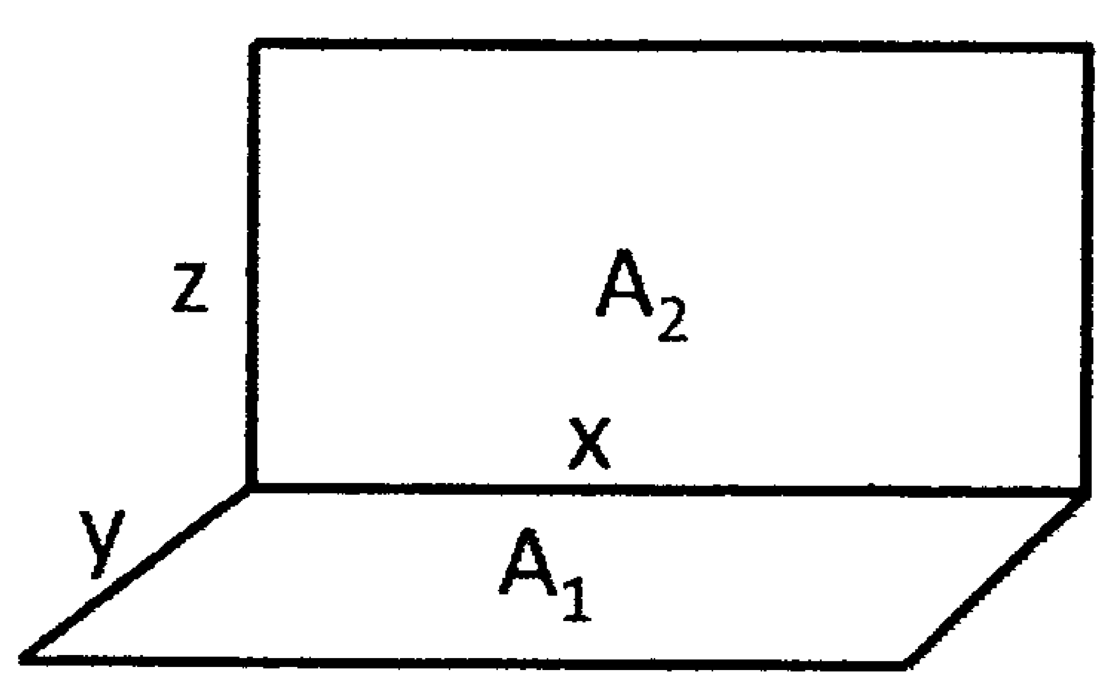
where ρ is the density, $\hat{C}_p$ the heat capacity per unit mass, T the temperature, $\underline{v}$ the velocity vector, and p the pressure of the fluid. The symbol t is for time. All physical properties are considered constant. If Fourier's law of heat conduction applies; viscous dissipation is neglected; and the fluid is an ideal gas, what form will the above equation be reduced to? (k is the thermal conductivity of the fluid.)

(A) $\rho \hat{C}_p \frac{DT}{Dt} = k\nabla^2 T + \frac{Dp}{Dt}$, (B) $\rho \hat{C}_p \frac{DT}{Dt} = k\nabla^2 T$, (C) $\rho \hat{C}_p \frac{\partial T}{\partial t} = k\nabla^2 T + \frac{Dp}{Dt}$,
(D) $\rho \hat{C}_p \frac{\partial T}{\partial t} = k\nabla^2 T$

9. A solid material occupying the space from y=0 to $y=\infty$ is initially at temperature T_0. At time t=0, the surface at y=0 is suddenly raised to temperature T_1 and maintained at that temperature for t>0. (α is the thermal diffusivity of the material.) What is the temperature profile?

(A) $\frac{T-T_0}{T_1-T_0} = erf(\frac{y}{\sqrt{4\alpha t}})$, (B) $\frac{T-T_0}{T_1-T_0} = erf(\frac{\sqrt{4\alpha t}}{y})$, (C) $\frac{T-T_0}{T_1-T_0} = 1-erf(\frac{\sqrt{4\alpha t}}{y})$,
(D) $\frac{T-T_0}{T_1-T_0} = 1-erf(\frac{y}{\sqrt{4\alpha t}})$.

10. Consider the view factor F_{12} of the following direct radiation between adjacent rectangles in perpendicular planes.



(A) F_{12} increases with increasing y/x; (B) F_{12} decreases with increasing z/x; (C) F_{12} increases with increasing z/x; (D) F_{12} is irrelevant with both z/x and y/x.

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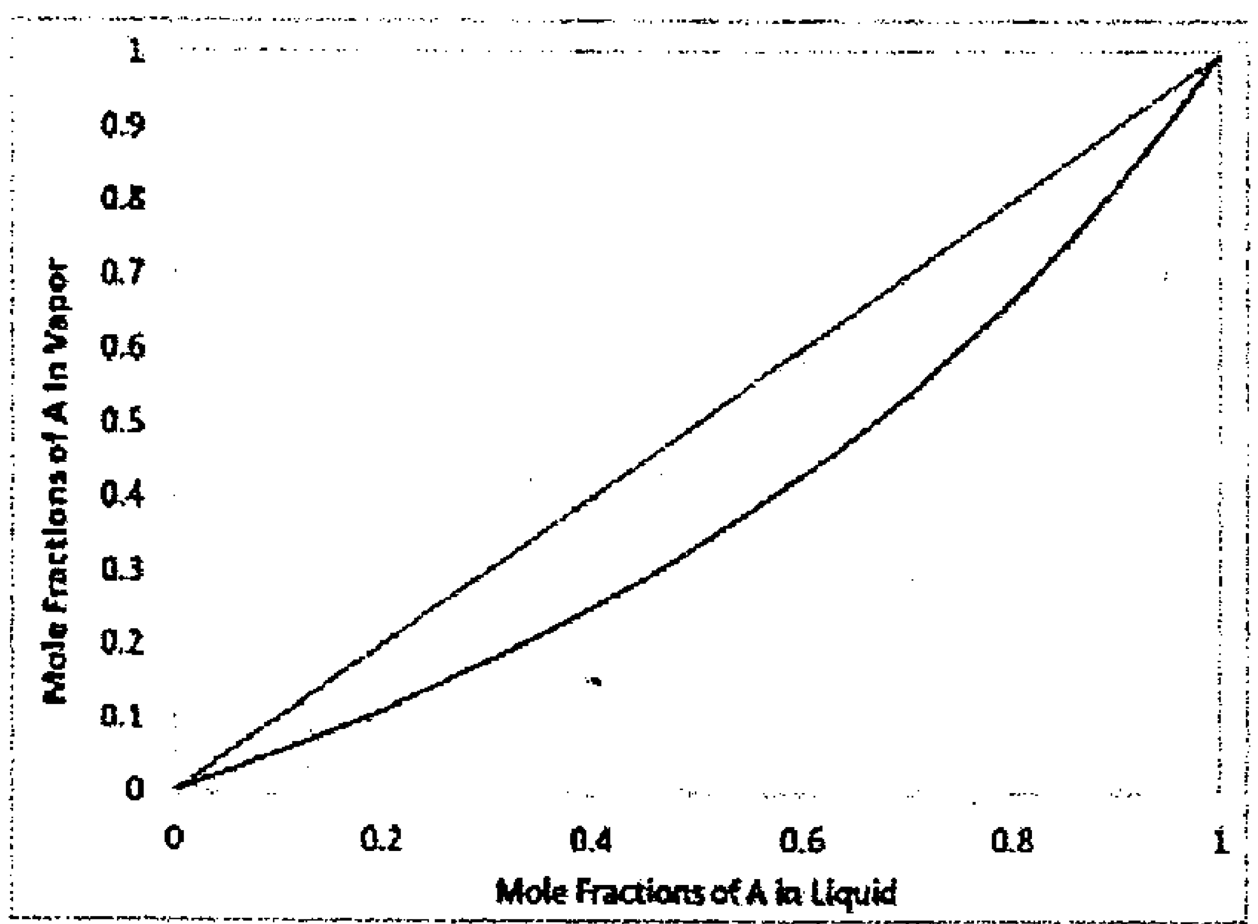
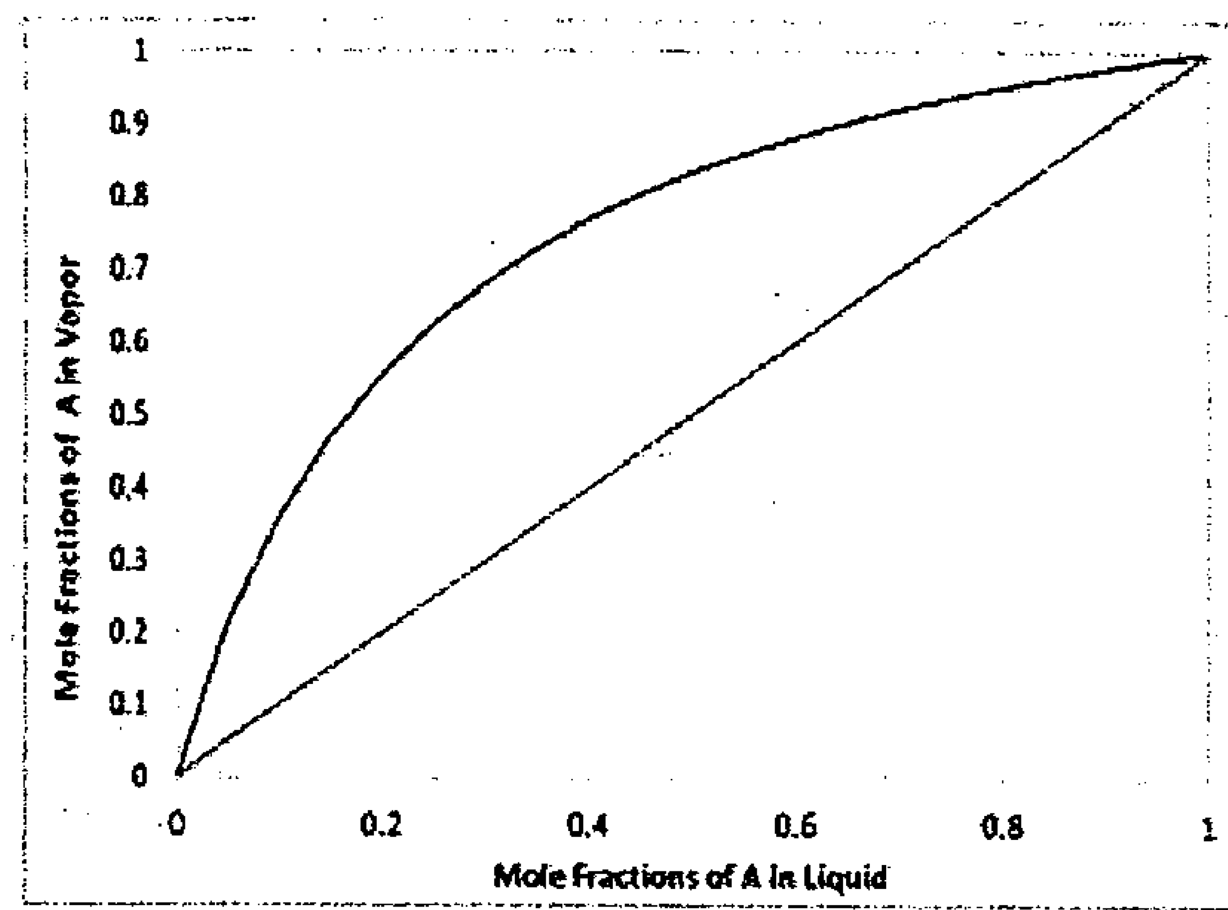
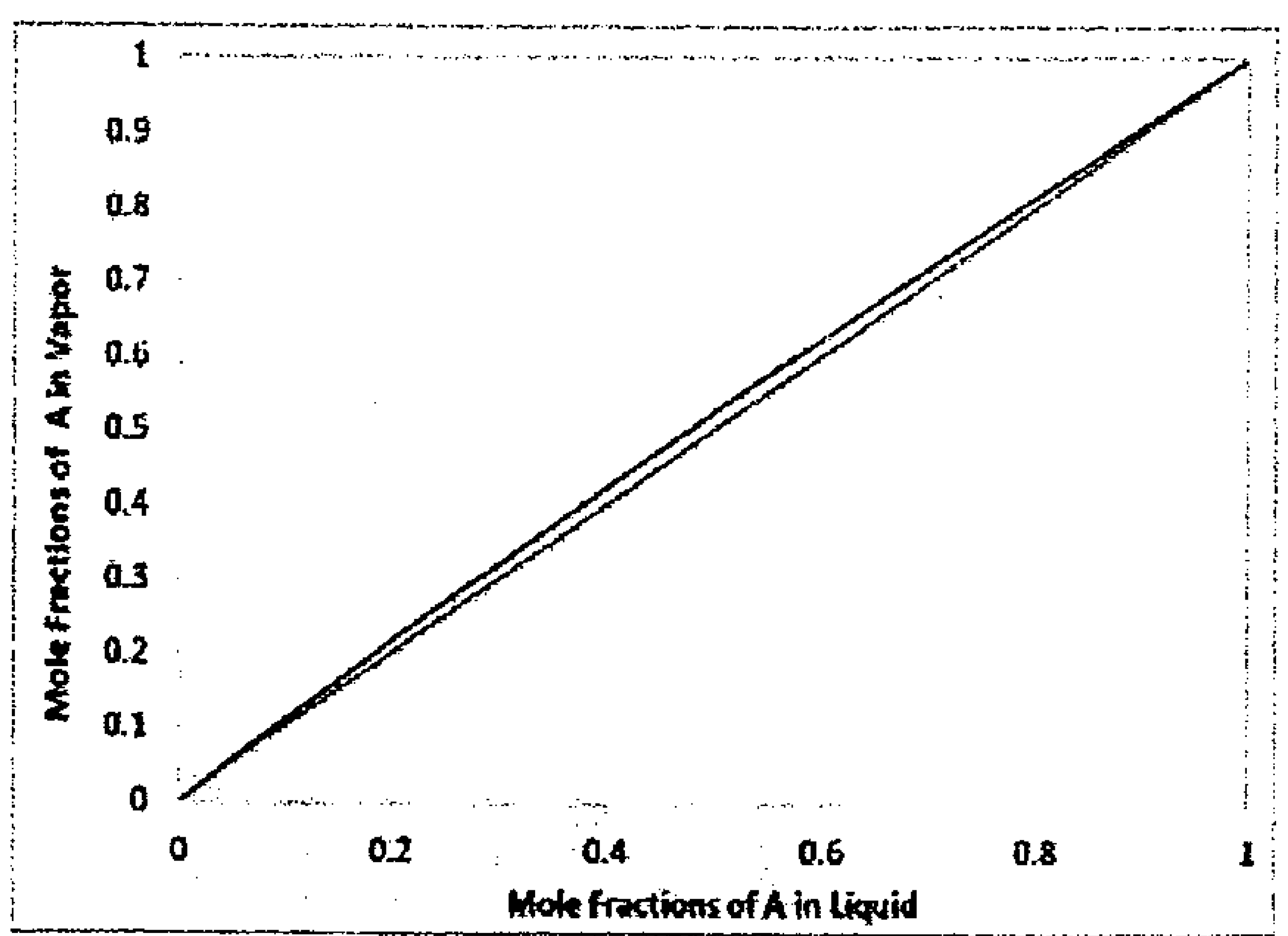


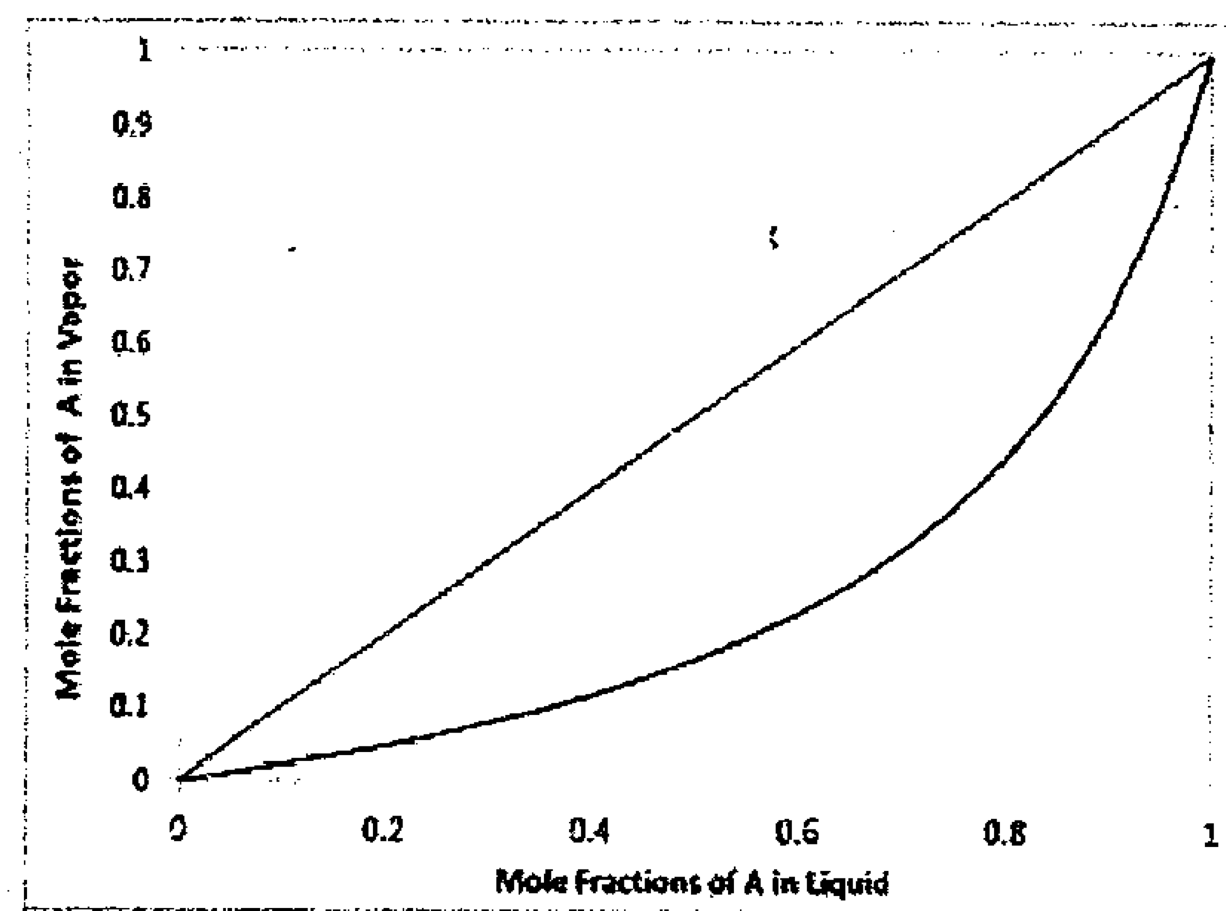
System 1



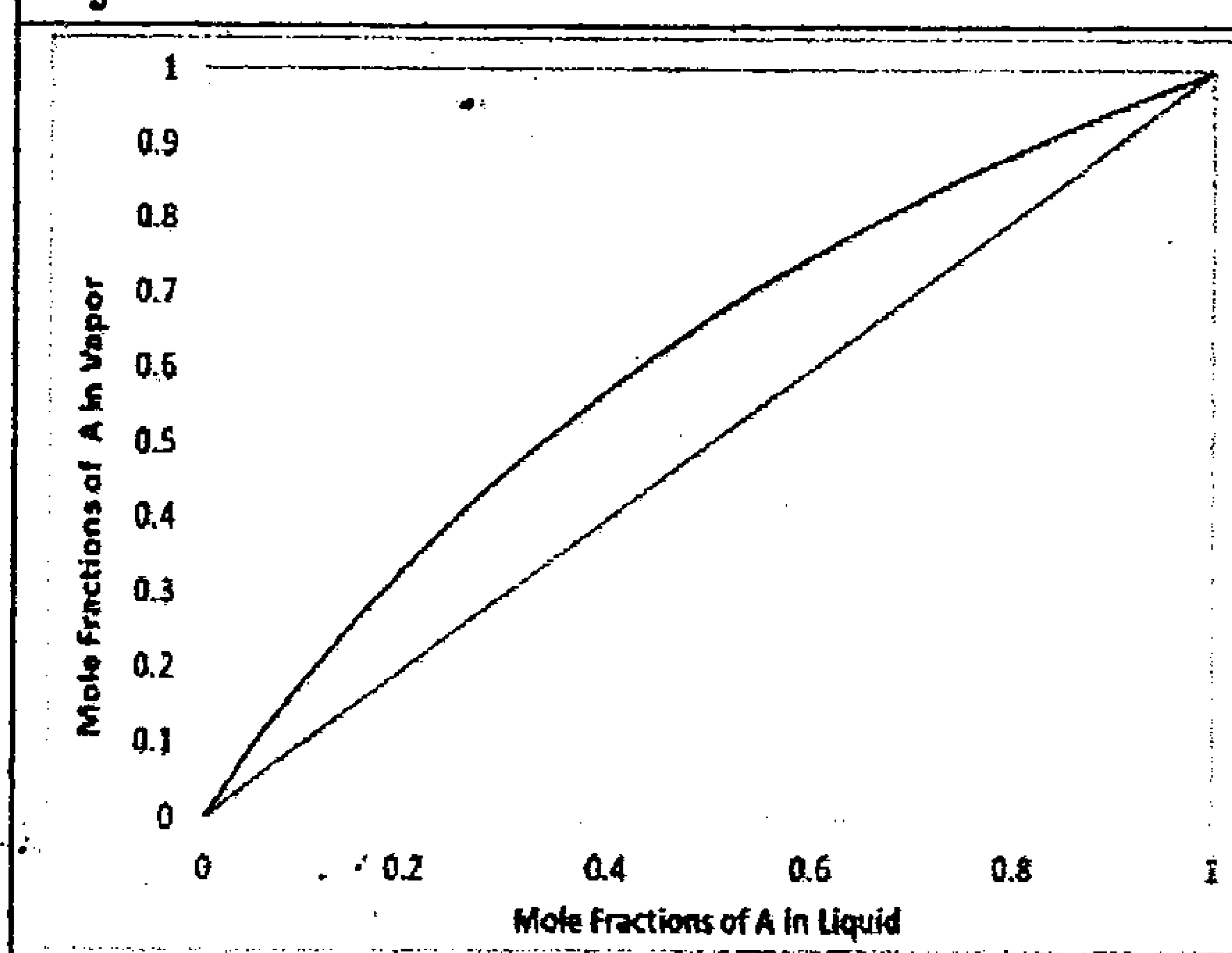
System 2



System 3



System 4



System 5

11 In which of the above systems A has the lowest relative volatility

A. System 1
B. System 2
C. System 3
D. System 4
E. System 5

12 In which of the above systems B has the highest relative volatility

A. System 1
B. System 2
C. System 3
D. System 4
E. System 5

13 In which of the above systems, separation of A and B is most difficult

A. System 1
B. System 2
C. System 3
D. System 4
E. System 5

14 In which of the above systems, separation of A and B is least difficult

A. System 1,5
B. System 2,4
C. System 1,2
D. System 4,5
E. System 3

15 In which of the above systems, A will come out at the top of a distillation column designed to separate A and B.

A. System 2,3,5
B. System 2,4,5
C. System 1,2,3
D. System 1,3,4
E. System 1,4

The Henry's coefficient of A in a nonvolatile solvent S1 is 2 atm, the Henry's Law coefficient of A in another nonvolatile solvent S2 is 0.5 atm. An inlet air stream at 1 atm containing 10 mol% of A, 90% of this A has to be removed from the air stream.

16 Which of the following is true ?.

A. S1 is a better solvent of A.

B. S2 is a better solvent of A.

C. Saturation solubility of A in S1 is 0.2.

D. Saturation solubility of A in S2 is 0.05.

E. None of the above

17 For a counter-current absorption column when fresh solvent (S1 or S2) is fed to the top of the column, and the air stream is fed to the bottom, which of the following is <u>not</u> true?

A. The equilibrium solubility of A in S1 at the outlet air stream is 0.005.

B. The equilibrium solubility of A in S2 at the outlet air stream is 0.02.

C. The driving force at top of the column using S1 is 0.005.

D. The driving force at bottom of the column is always 0.

E. None of the above

18 Two moles of S2 is used per mole of inlet air stream a counter-current absorption column with 3 equilibrium stages. Fresh solvent S2 is fed to the top of the column, and the air stream is fed to the bottom; what is the concentration of the solution coming out of the solvent

A. =0.043

B. >0.043 but <0.048

C. <0.043 but >0

D. =0.2

E. >0.2

19 Two moles of S2 is used per mole of inlet air stream a counter-current absorption column with 1 equilibrium stage. Fresh solvent S2 is fed to the top of the column, and the air stream is fed to the bottom; what is the concentration of the solution coming out of the solvent

A. =0.048
B. =0.043
C. >0.043 but <0.048
D. <0.043 but >0.002
E. ≤0.002

20　0.2 moles of S2 is used per mole of inlet air stream a counter-current absorption column with 10 equilibrium stages.　Fresh solvent S2 is fed to the top of the column, and the air stream is fed to the bottom; what is the concentration of the solution coming out of the solvent

A. =0.333
B. =0.310
C. >0.310 but <0.33
D. <0.310 but >0.2
E. <0.2

以下六題，請於答案卷作答

Problem 1 (10%) A 0.04 m inside diameter, 0.048 m outside diameter, 4 m long, standard steel pipe is used to condense steam on its outer surface, by flowing water through it. The inside and outside heat transfer coefficients are 2250 W/m^2-°C and 10000 W/ m^2-°C, respectively. The thermal conductivity of the steel pipe is 43 W/ m-°C. The temperature difference of steam and water at the water entrance section ($\triangle T_1$) is 110 °C, and that at the water outlet section ($\triangle T_2$) is 50°C.

a) Calculate the overall heat transfer coefficient based on the inside area.

b) Calculate the rate of heat transfer to water, expressed in kW.

Problem 2 (10%) Air at 101.3 kPa and an average of 477.6K (Hint: this is the temperature at which all air physical properties should be evaluated, unless specified otherwise) is being heated as it flows through a tube of 25.4 mm inside diameter at a velocity of 7.62 m/s. The heating medium is 491.5 K steam condensing on the outside of the tube. It is assumed that the only significant heat transfer resistance is the inside air film, thus it is assumed that the inside metal wall temperature is also 491.5 K. Calculate the heat transfer coefficient, using the empirical equation:

$$N_{Nu}=h\,D/k=0.027\,N_{Re}^{0.8}N_{Pr}^{0.33}(\mu_b/\mu_w)^{0.14},$$

where h is the heat transfer coefficient, D is the diameter of the tube, k is the thermal conductivity of air. μ_b and μ_w are the values of viscosity of air evaluated at the bulk and wall temperatures, respectively. Use data from the following table for your calculation.

Table: Physical properties of air at 101.325 kPa

T (K)	ρ (kg/m^3)	μx10^5 (Pa-s or kg/m-s)	K (W/m-K)	N_{Pr}
255.4	1.379	1.62	0.02250	0.720
283.2	1.246	1.78	0.02492	0.713
311.0	1.137	1.90	0.02700	0.705
366.5	0.964	2.15	0.03115	0.694
394.3	0.895	2.27	0.03323	0.692
422.1	0.838	2.37	0.03531	0.689
449.9	0.785	2.50	0.03721	0.687
477.6	0.740	2.60	0.03894	0.686
505.4	0.700	2.71	0.04084	0.684

The flow field of a two-layer curtain coating operation is shown in the figure. The two fluids are Newtonian with viscosities μ_1 and μ_2, and densities ρ_1 and ρ_2, respectively. We may neglect the end effects and assume the fluid flow is fully-developed. The flow field can be divided into four sections, i.e., (A) slot section, (B) slide section, (C) curtain section and (D) web section.

Problem 3 Which of the following statement(s) is (are) correct? (10%)

(a) The flow becomes turbulent if there is a vortex in the top of Section A for fluid 2.

(b) The shear force at the intersection of the two layers should be zero to avoid inter-layer mixing in Section B.

(c) The maximum velocity appears at the surface of the out layer in Section C.

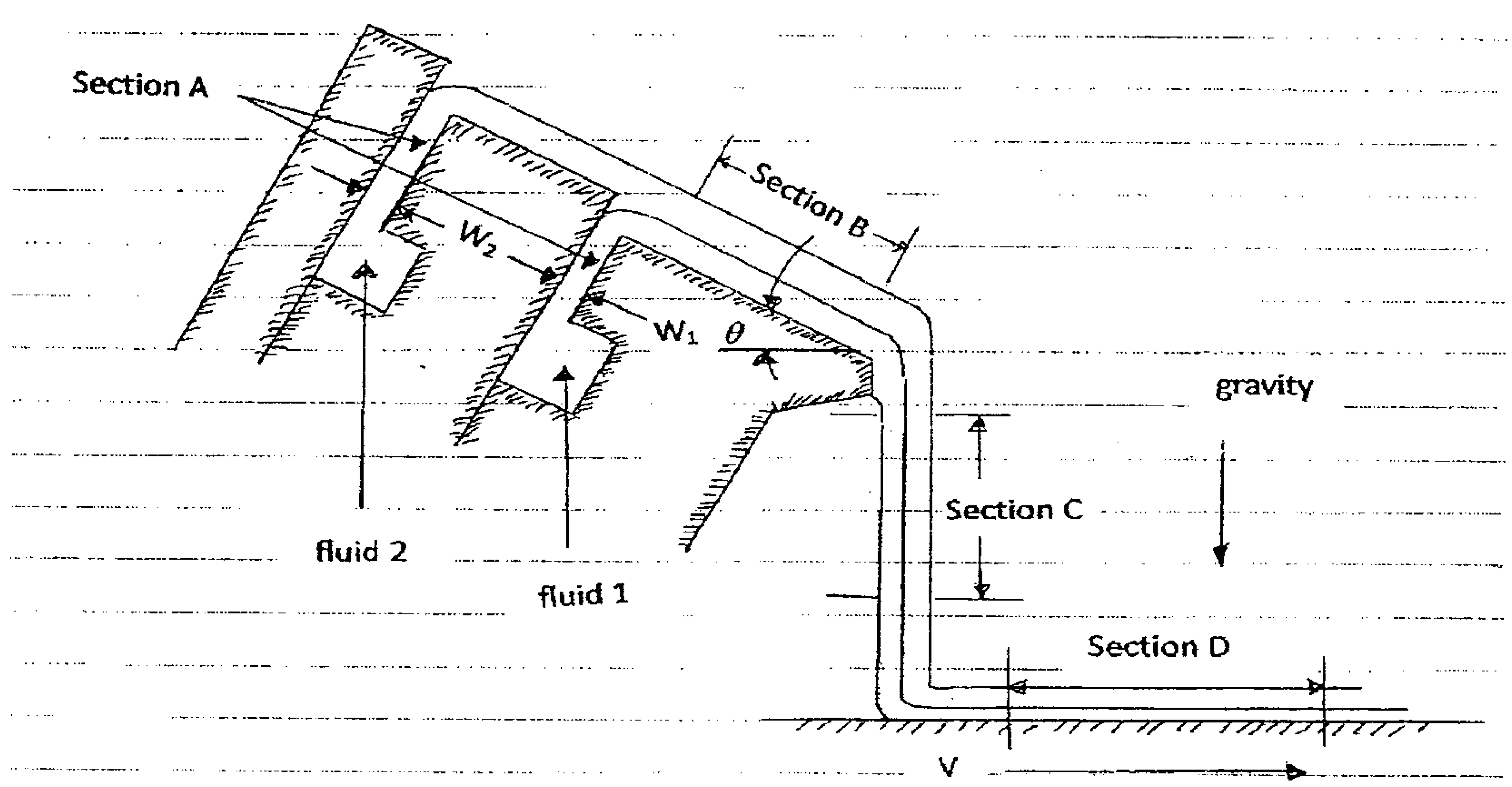
(d) The maximum velocity appears at the top surface in Section D.

(e) The average velocity for fluid 1 in Section A has to be small to avoid inter-layer mixing.

Problem 4 If the maximum velocities are S_1 and S_2 for fluids in the two slots in section A,

(a) Can you relate S_1 and S_2 to the coated film thickness of the top layer in Section D? (5%)

(b) Can you determine the maximum velocity in Section B? (5%)



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Problem 5

(a) Which of the following dimensionless group(s) is (are) significant for the process of slow sublimation of a naphthalene ball in a stagnant air? (3%)

(1) Schmidt number　　(2) Reynolds number　　(3) Stanton number

(b) For a binary system, the diffusion molar flux $\underline{N_A}$ can be described as Fick's first law:　　$\underline{N_A} = x_A(\underline{N_A} + \underline{N_B}) - cD_{AB}\underline{\nabla x_A}$

(i) State the physical meanings of the two terms on the right-hand side. (3 %)

(ii) Can you apply this equation if D_{AB} is not a constant? (2 %)

Problem 6　A solid A is dissolving in a flowing liquid stream S in a steady-state, isothermal flow system. Assume in accordance with the film model that the surface of A is covered with a stagnant liquid film of thickness δ and that the liquid outside the film is well mixed.

(a) Develop an expression for the rate of dissolution of A into the liquid if the concentration of A in the main liquid stream is negligible. (4%)

(b) Develop a corresponding expression for the dissolution rate if the liquid contains a substance B, which, at the plane $z = \kappa\delta$, reacts instantaneously and irreversibly with A: $A+B \rightarrow P$. The main liquid stream consists primarily of B and S, with B at a mole fraction of $x_{B\infty}$ **(see the figure below)**.　(8%)

(Hint: It is necessary to recognize that species A and B both diffuse toward a thin reaction zone as shown in the figure below.)

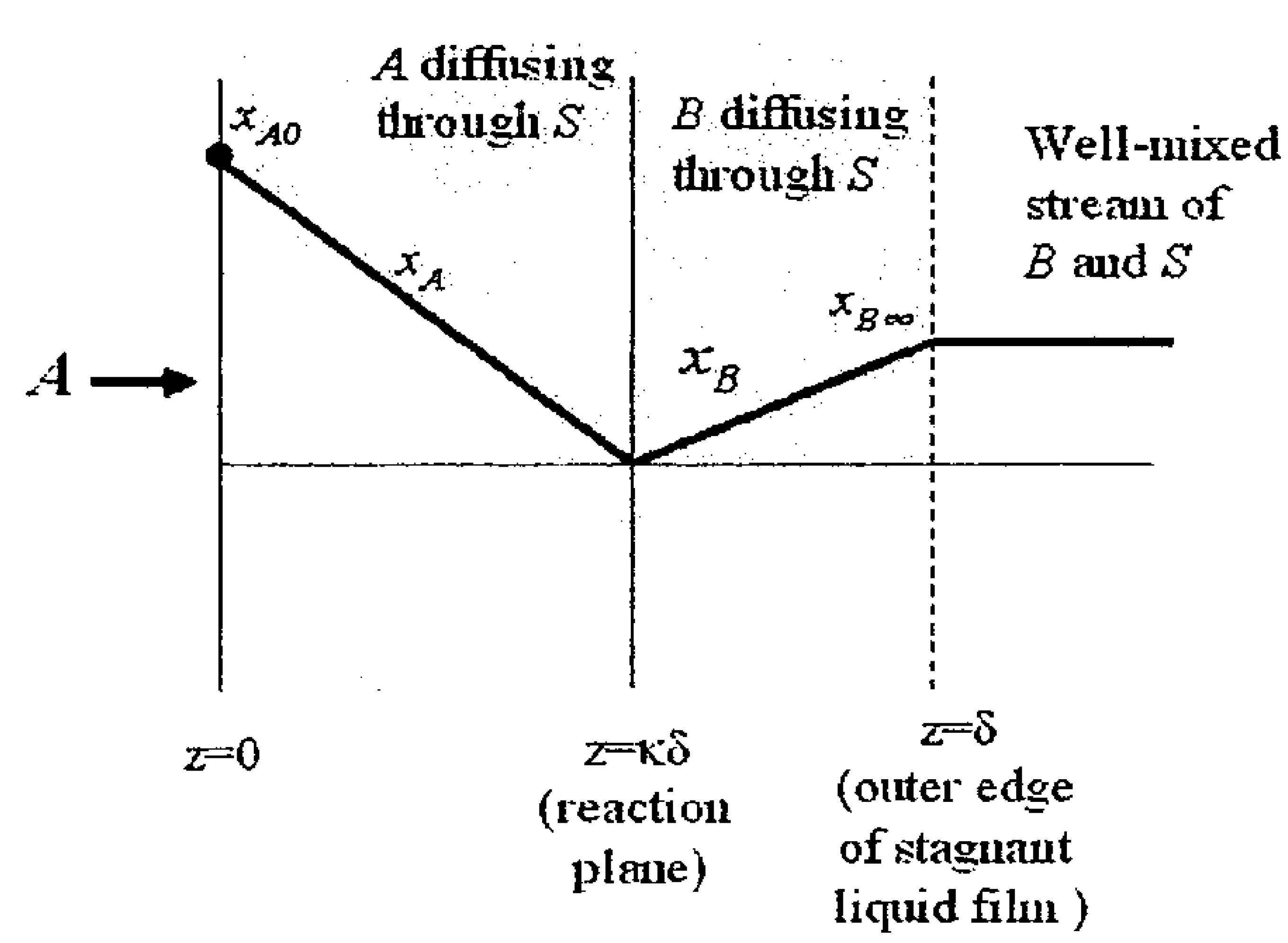

Figure. Concentration profiles for diffusion with rapid second-order reaction. The concentration of product P is neglected.