國立清華大學 101 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【答案卷、卡】作答

Problem 1

(1)The below are y-x and T-y-x diagrams of a binary liquid mixture containing chloroform and acetone at 1 atm. A feed stream containing 30 mol% of chloroform is to be processed.

(a) (2%) If near pure acetone is produced using continuous distillation at atmospheric pressure, will it be recovered as a distillate or a bottom product?

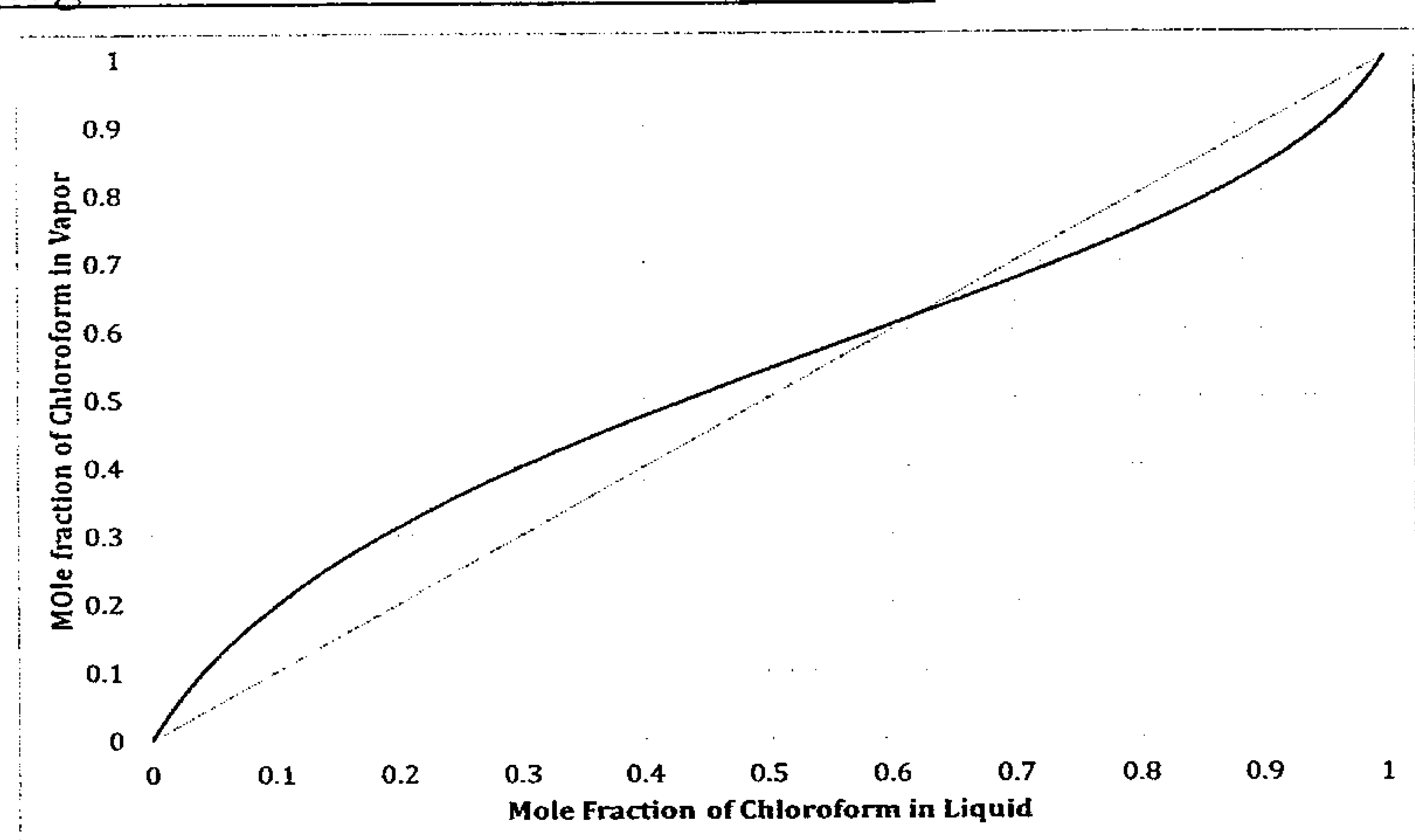
(b) (2%) If near pure acetone is produced using continuous distillation at atmospheric pressure, what is the temperature of the other product?

(c) (2%) What is the maximum amount of near pure acetone that can be produced using continuous distillation at atmospheric pressure?

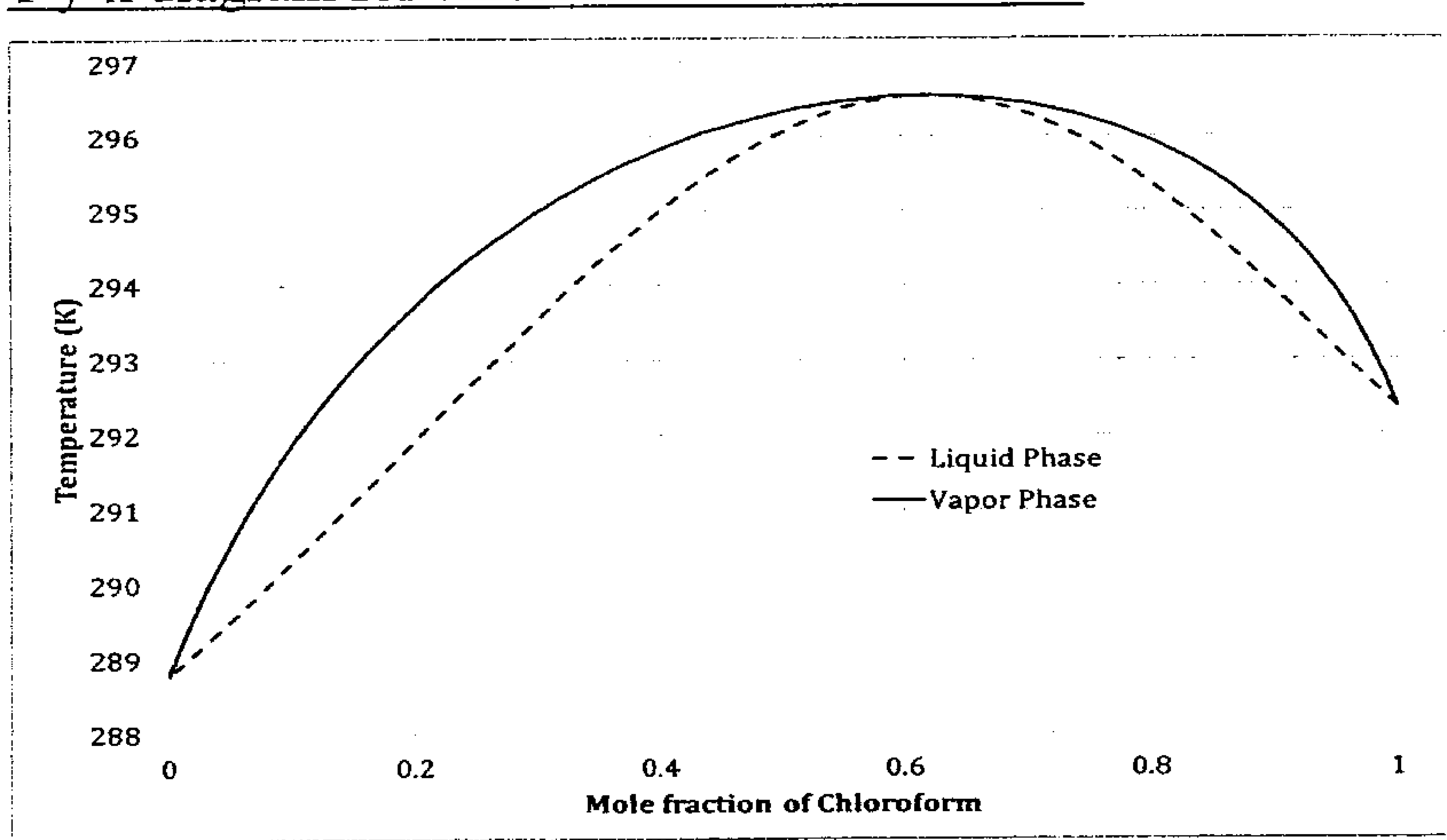
(d) (2%) If batch distillation is used, what is the composition of the first drop of product produced?

(e) (2%) If batch distillation is used, what is the composition of the last drop of product that remained in the still?

y-x diagram for chloroform-acetone at 1 atm



T-y-x diagram for chloroform-acetone at 1 atm



Problem 1

(2)Below is the solubility (in terms of mole fraction) of carbon dioxide (CO_2) in methanol. Suppose methanol is used to remove 90% CO_2 from 1000 kmol/hr of a feed air stream at 10 Bar with an inlet CO_2 partial pressure of 4 Bar.

(a) (1%) How many moles of CO_2 have to be removed?

(b) (1%) What is the Henry's Law coefficient of CO_2 in methanol?

(c) (1%) What is the concentration of the solution coming out of the bottom absorber if it is saturated with the feed air stream?

(d) (1%) How many moles per hour of fresh methanol have to be used if the solution coming out of the bottom absorber is saturated with the feed air stream?

(e) (1%) How many moles per hour of spent methanol with CO_2 mole fraction 0.002 have to be used if the solution coming out of the bottom absorber is saturated with the feed air stream?

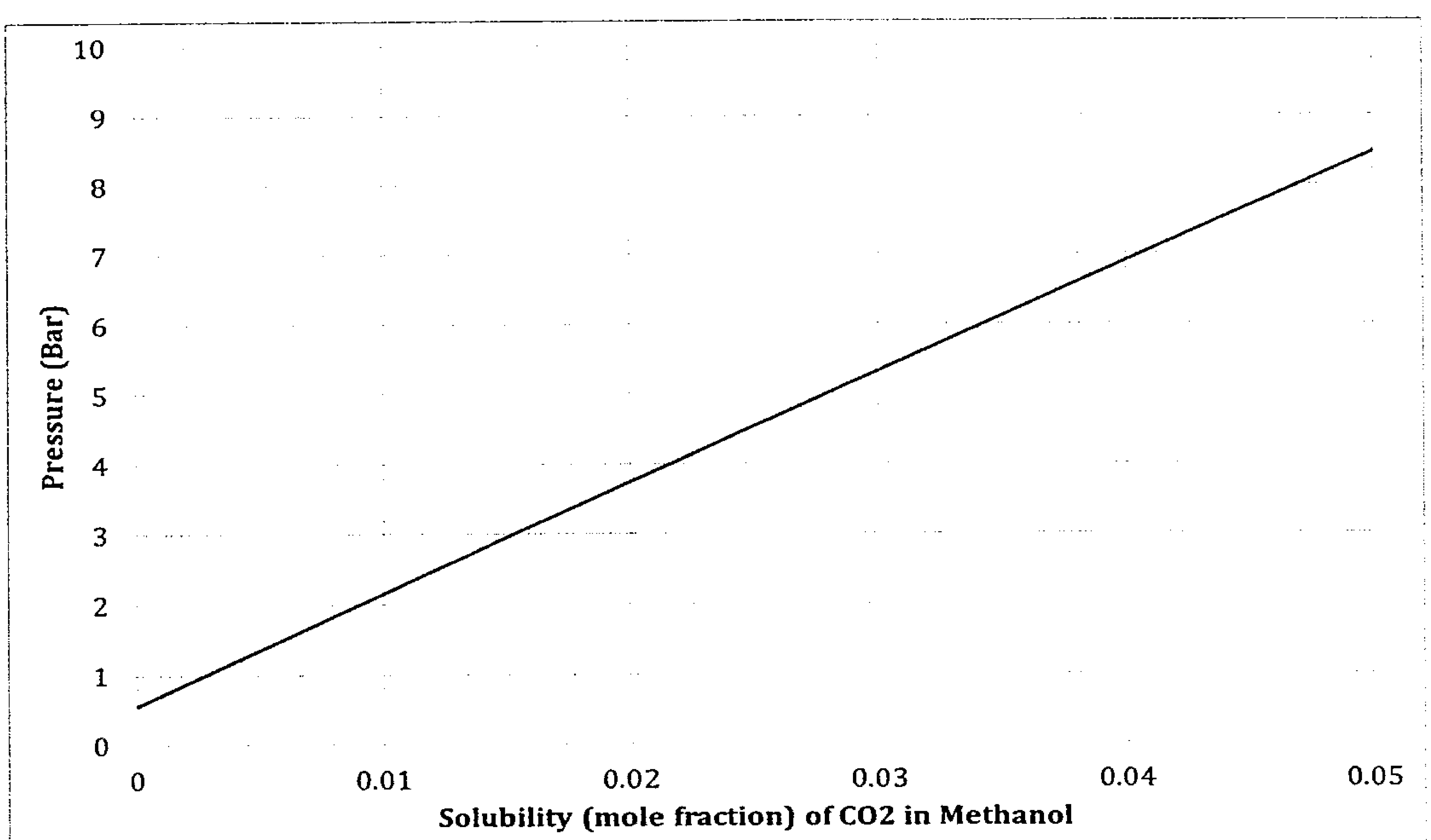
(f) (1%) What is the mass transfer driving force at the top of the column in case (d)?

(g) (1%) What is the mass transfer driving force at the bottom of the column in case (d)?

(h) (1%) What is the mass transfer driving force at the top of the column in case (e)?

(i) (1%) What is the mass transfer driving force at the bottom of the column in case (e)?

(j) (1%) What is the log mean mass transfer driving force of the column in case (e)?



Problem2

Consider the liquid film drying process as shown in the figure, a substrate with coated liquid film is moving into the oven horizontally. Hot air jets are impinging on the film surface from the slit nozzles. The coated liquid film consists of spherical solid particles (10% weight) with average diameter around 5 micro-meters, an organic solvent (80% weight) and a polymer (10% weight) that serves as a binder and is dissolved in the solvent. The initial liquid film thickness H is 150 micro-meters.

(1) There are five statements below, please select the statement(s) that is (are) correct. (10%)

(a) The average film thickness after drying should be between 15 and 30 micro-meters.

(b) Since natural convection can improve heat transfer, the temperature of the impinging hot air jets on the moving substrate should be high enough to create natural convection inside the liquid film to improve the dry film quality.

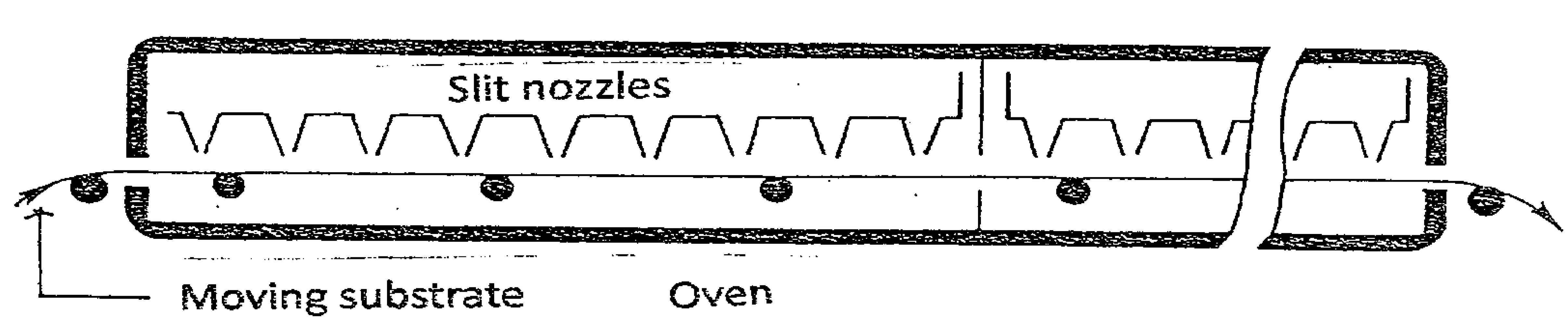
(c) The air velocities of the nozzle jets above the liquid film should be strong enough to break the air boundary layer on the liquid film surface to improve the drying efficiency.

(d) Bubbles that may appear on the dry film surface are caused by the chemical reaction inside the film.

(e) The drying time can be shortened if the substrate is copper foil instead of polyester film.

(2) Set up a mathematical model that is in the form of one-dimensional partial differential equation with proper initial and boundary conditions to predict the temperature distribution inside the liquid film 5cm from the oven entrance. List your assumptions. You do not need to solve the equation. (5%)

(3) Can you set up an overall energy balance to estimate the rate of energy input that is sufficient to dry the film in the oven? You are free to define any variables necessary. Energy is required to raise the temperature of the coated film, substrate and latent heat for solvent evaporation. (5%)



Problem3

(1)Answer the following questions regarding mass transport:

(a) Write down the definitions and units of the following parameters:

(i) mass diffusivity (2%)

(ii) molecular molar fluxes (2%)

(b) Identify the conditions that the Fick's second law is applicable. (2%)

(c) Define the term "diffusion-controlled reaction". (3%)

(2) Assume a power series velocity distribution and a power series concentration profile of component A in the laminar boundary layer over a flat plate:

$v_x = a + by + cy^2$

$C_A - C_{As} = \alpha + \beta y + \gamma y^2$

The von Karman integral equation of concentration boundary layer is given by:

$$-D_{AB}\left.\frac{\partial C_A}{\partial y}\right|_{y=0} = \frac{d}{dx}\int_0^{\delta_c} v_x (C_A - C_{A\infty})dy$$

(a) Define the following parameters appeared in the above equations:

C_{As}, $C_{A\infty}$ and δ_c. (2%)

(b) Apply the boundary conditions for a laminar boundary layer and evaluate the velocity and concentration profiles. (4%)

(c) Develop expressions for the "mean Sherwood number" and "local Sherwood number" for a fluid flowing past a plate with a length of L and a width of W. (5%)

Problem4

Humidification Operations

(1) What is wet bulb temperature T_W? Please draw a schematic diagram to illustrate your explanation. What is the relation between wet bulb temperature and adiabatic saturation temperature T_S ? (10%)

(2) Derive the so-called psychrometric line slope $-h_y/(M_B k_y \lambda_W)$ on a humidity H versus temperature T chart from both the heat and mass transfer considerations related to wet bulb temperature (here: h_y and k_y are heat and mass transfer coefficients between the gas and surface of water, λ_W is the latent heat of water at T_W and M_B is the molecular weight of gas) . Make necessary and reasonable assumptions to simplify this relationship. What is the Lewis relation when the adiabatic saturation line is nearly identical to the psychrometric line? (10%)

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Problem5

A fluid flows in the the positive x-direction through a long flat duct of length L, width W, and thickness B, where L>>W>>B. The duct has porous walls at y=0 and y=B, so that a constant cross flow can be maintained, with $v_y = v_0$, a constant, everywhere. Flows of this type are important in connection with separation processes using the sweep-diffusion effect. By carefully controlling the cross flow, one can concentrate the larger constituents(molecules,dust particles,etc.) near the upper wall.

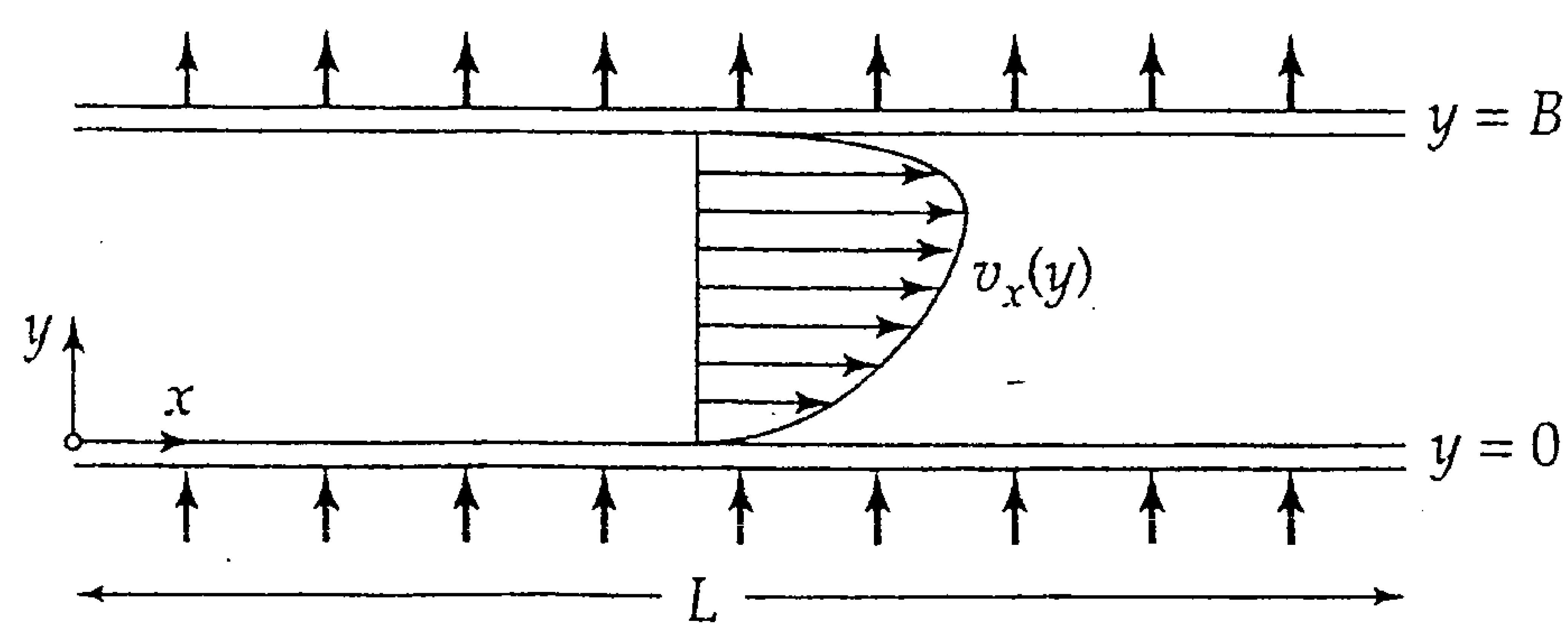

Fig.A. Flow in a slit of length L, width W, and thickness B. The walls at y=0 and y=B are porous, and there is a flow of the fluid in the y direction, with a uniform velocity $v_y = v_0$.

(1) Find the velocity profile for the system. (10%)

(2) Find the mass flow rate in the x direction. (10%)