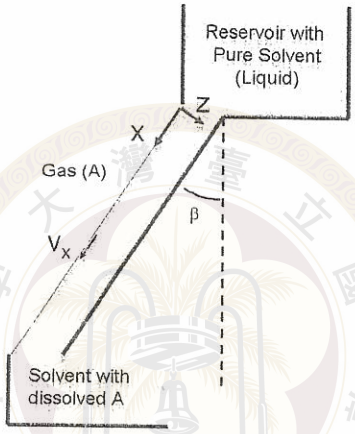
非選擇題（請寫題號並依題號順序作答）

1. (10%) Please state the definitions and physical meanings of the following dimensionless groups (2% each): Darcy drag coefficient, Colburn j factor, Prandtl number, Sherwood number, Peclet number.

2. Consider a thin liquid film with the thickness δ flows slowly down an inclined flat plate of width W, as shown in the following figure. One side of the liquid film wets the surface and the other side of the film is in contact with gas A. Gas A is soluble in the liquid. The liquid flow velocity along the plane is v_x. The liquid exposes to the gas from x = 0 to x = L. The diffusivity of A in the liquid is D while the viscosity and density of the liquid are μ and ρ, respectively. (You may define extra variables if needed)



To simplify this problem, we make the following assumptions:

(i) The flow is laminar flow; neglect the end effect if there is any.

(ii) There is no resistance to diffuse in the gas phase.

(iii) The contact (time) of the gas and the liquid is short with respect to the time requires for the gas to penetrate through the liquid film.

(iv) Dissolving of A in the liquid does not change the liquid properties.

Answer the following questions:

(a) (10%) Start from shell balance, find the velocity profile $V_x(z)$.

(b) (10%) Derive and solve the differential equation (and list proper boundary conditions) that describes the concentration of A (C_A) in the liquid as a function of x and z. State the assumptions needed.

(c) (5%) Find the total molar flow of A across the surface at z=0.

3. A homogeneous metal sphere of radius R with uniform initial temperature T_I is suddenly immersed (at time t=0) in a gas stream of temperature T_f. The thermal conductivity, density, and heat capacity of the metal are k, ρ, and Cp, respectively. The convection coefficient between the metal sphere surface and the gas is h. Answer the following questions (You may define extra variables if needed):

(a) (10%) Start from shell balance, derive the time dependent partial differential equation and list the boundary and initial conditions in a dimensionless form that describes the temporal and spatial temperature distribution of this metal sphere.

(b) (10%) If this metal sphere is to be used as the thermocouple junction, what criteria are required? If any

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quantities are used for the justification, clearly state how these quantities are obtained and how they influence the thermocouple junction response. (Note that the requirements for a thermocouple junction are (i) the temperature rising (or falling) time of the junction should be short and (ii) the temperature of the junction needs to be nearly uniform.)

4. (15%) A straight cylindrical fin of diameter 5 mm and length 5 mm was made of copper (386 W/m-K and 8890 kg/m^3) which is attached on an isothermal surface of 100°C to enhance the heat transfer rate to the surrounding air at atmospheric pressure and 25°C. The bulk air is still so the heat transfer coefficient is estimated around 10 W/m^2-K. Please estimate the heat loss from the attached fin.

5. (15%) The copper in an aqueous solution (2.0 kg Cu m^{-3}) is to be extracted with kerosene-resin solution using a three-stage countercurrent extractor. The equilibrium data are as follows

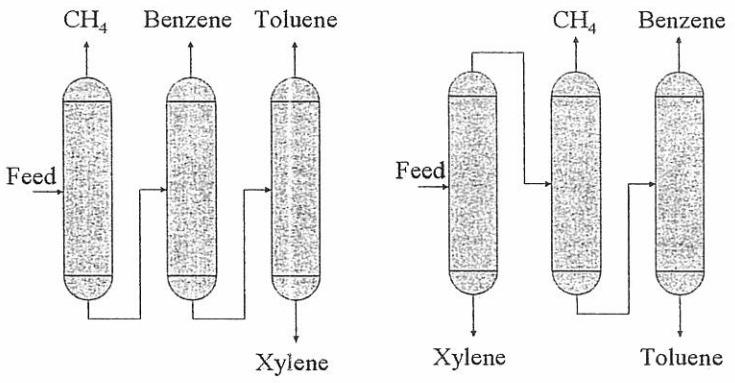
X, kg Cu m^{-3} aqueous solution	0.1	0.3	0.7	1.5	2.0
Y, kg Cu m^{-3} organic solution	0.3	0.8	1.9	3.0	3.5

Calculate the minimum flow rate of organic phase to extract the organic stream flowing at 1000 m^3 d^{-1} to an effluent copper concentration of 0.1 kg m^{-3}.
Calculate the copper recovery ratio if the flow rate of organic phase is 1.5 times to the minimum flow rate.

6 (15%). There is a mixture with the following compositions:

	Boiling point (°C)	Composition (% w/w)
Methane	-161	30
Benzene	80	5
Toluene	110	5
Xylene	144	60

Please propose which separation sequences (as follows) is a better design with multi-stage distillation columns to separate this mixture into product streams of purity>99% each. Explain clearly your reasons.



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