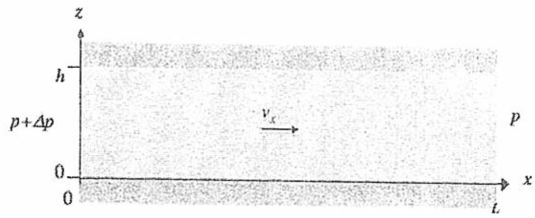
國立臺灣大學99學年度碩士班招生考試試題

Problem 1 (25 %)

Consider a one-dimensional, rectangular microfluidic channel whose aspect ratio is so large that the channel is well approximated by an infinite parallel-plate configuration. The geometry is shown in Figure 1.

a. Please derive the governing equations and the boundary conditions for this system, and state clearly all the assumptions made. (12%)
b. Derive the velocity profile and the volumetric flow rate through a section of width w. (13%)



< Figure 1 >

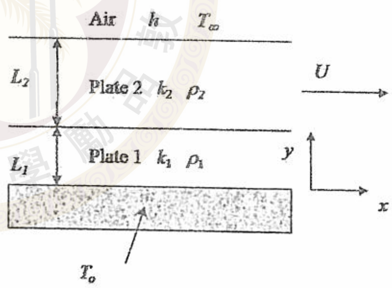
Problem 2 (25%)

Two solid plates of differing thermal properties are in contact as shown in Figure 2. The bottom surface of plate 1 is at constant temperature T_o, and at the top surface of plate 2 there is convective heat transfer with heat transfer coefficient h to the ambient air at temperature T_∞. The plate dimensions in the x and z directions are sufficiently large that $T=T(y)$. The rate of frictional heating H_s at the contact surface between the two plates is given by

$$H_s = c\gamma U$$

where U is the relative velocity of the plates, c is the coefficient of dry friction, and γ is the force per unit area holding the plates in contact.

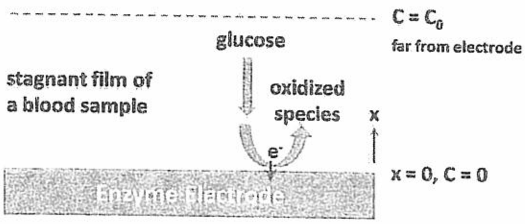
a. Determine the steady-state temperature profile when U=0. (13%)
b. Suppose that plate 2 moves horizontally at speed U, plate 1 remaining stationary. The plates are held in contact only by gravity. Find the temperature profile in this case. (12%)



< Figure 2 >

Problem 3 (30%)

Consider a blood glucose sensing process occurring at a planar enzyme electrode as illustrated in Figure 3 and answer the following questions.



< Figure 3 >

a. Assume that the distance between the top of the blood sample and the electrode surface is 0.1 cm, and the diffusion coefficient of glucose in blood is *ca.* 5 x 10^{-6} cm^2/s. Estimate how long a glucose molecule would take for traveling from the top of blood sample to the electrode surface by simple diffusion. (8%)

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b. Assume that the glucose sensing process is under diffusion control. In this case, glucose is totally oxidized at the electrode surface ($C = 0$ at $x = 0$), but glucose far away from the electrode surface is not affected by the biosensing process. Take advantage of Fick's second law with semi-infinite boundary conditions to show that the glucose concentration profile can be expressed as follows. (12%)

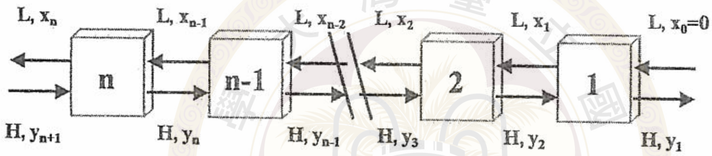
$$C(x,t) = C_0 erf\left[\frac{x}{2(Dt)^{1/2}}\right], \text{ where } erf(u) \equiv \frac{2}{\pi^{1/2}}\int_0^u e^{-y^2} dy$$

Note: x is the distance from the electrode surface; t is time; $C(x,t)$ and C_0 represent the glucose concentration at x and t and the initial glucose concentration; D is the diffusion coefficient of glucose.

c. According to Faraday's law, the sensing current is proportional to the mass flux of glucose at the electrode surface ($x = 0$). Take advantage of Fick's first law and show that the reacted charge collected by the electronic coulometer is proportional to $C_0(Dt)^{1/2}$. (10%)

Problem 4 (20 %)

a. Consider an ideal sta ged countercurrent extraction cascade shown schematically in Figure 4.



< Figure 4 >

H and L are the flow rates (liters per hour) of the immiscible feed and extract, respectively; y and x are the mass concentrations of the dilute solute being transferred from H to L. For stage n, the entering mass fractions are x_{n-1} and y_{n+1}; the exiting mass fractions are x_n and y_n. The solute is dilute, so we expect that the equilibrium is linear and can be expressed as $y_n = mx_n$. Take advantage of mass balance for solute change between H and L to show that for N stage y_{N+1} can be expressed as follows.

$$y_{N+1} = \left[\frac{\frac{1}{E^{N+1}} - 1}{\frac{1}{E} - 1}\right] y_1$$

where E (= mH/L) is the extraction factor. (10%)

b. A clarified fermentation beer H containing 260 milligram per liter of actinomycin is to be extracted using butyl acetate L. Because the beer's pH is 3.5, the equilibrium coefficient m is 0.02. You plan to let H equal 500 liters per hour and L equal 50 liters per hour. You want to recover ninety-nine percent of the antibiotic in the feed. How many equilibrium stages will you need to accomplish this separation? (Hint: $log\ (a+1) \sim log\ a$, when $a >> 1$; $\log 2 = 0.301$.) (10%)

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