編號： 79　　　　　　國立成功大學 104 學年度碩士班招生考試試題

系所組別：化學工程學系甲組

考試科目：單元操作與輸送現象　　　　　　　　　　　　　　　　　考試日期：0211，節次：1

※ 考生請注意：本試題可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

Equations:

The shear stress components in cylindrical coordinates

$$\tau_{r\theta} = \tau_{\theta r} = \mu\left[r\frac{\partial}{\partial r}\left(\frac{\upsilon_\theta}{r}\right) + \frac{1}{r}\frac{\partial \upsilon_r}{\partial \theta}\right]$$

$$\tau_{z\theta} = \tau_{\theta z} = \mu\left[\frac{\partial \upsilon_\theta}{\partial z} + \frac{1}{r}\frac{\partial \upsilon_z}{\partial \theta}\right]$$

$$\tau_{zr} = \tau_{rz} = \mu\left[\frac{\partial \upsilon_z}{\partial r} + \frac{\partial \upsilon_r}{\partial z}\right]$$

Problems

1. Answer the following: (15%)
   (a) What is the Stefan-Boltzmann law in thermal radiation?
   (b) What is the difference between the natural convection and forced convection?
   (c) What is the definition of heat exchanger effectiveness (ε)?
   (d) What are the differences between the Nusselt number and the Biot number in terms of the variables employed and their physical significance?
   (e) What is the definition of economy of an evaporator?

2. A long pipe with inner radius r_i, outer radius r_o and the length L, is covered with thermal insulation with radius R. Pease derive the critical radius of the thermal insulation in terms of the thermal conductivity of the pipe, k, and the heat transfer coefficient, h. The temperatures of the pipe and the surrounding air are T and T_a, respectively (8%). For the insulation with critical radius, is the heat loss maximum or minimum? (2%)

3. The Navier-Stokes equation in two-dimensional form can be written in the following.

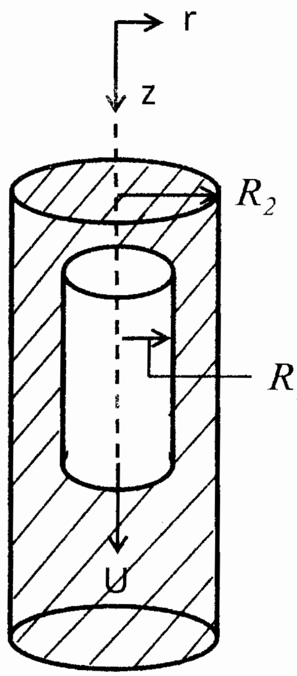
$$\rho\left(\frac{\partial \vec{\upsilon}}{\partial t} + \upsilon_x\frac{\partial \vec{\upsilon}}{\partial x} + \upsilon_y\frac{\partial \vec{\upsilon}}{\partial y}\right) = \rho\vec{g} - \nabla p + \mu\left(\frac{\partial^2 \vec{\upsilon}}{\partial x^2} + \frac{\partial^2 \vec{\upsilon}}{\partial y^2}\right)$$

   Derive the dimensionless equation using dimensional analysis. The reference length and velocity are L and υ_∞, respectively. Write down the physical meanings of the derived dimensionless parameters. (6%)

4. Please briefly descript how to calculate the hydraulic horse power of a pump in order to transport a fluid from tank A to tank B, which are operating at the pressure of P_1 and P_2, respectively. The elevations of tank A and tank B from the pump are y_1 and y_2, respectively. You have to write down a basic equation and draw a schematic diagram. (6%)

5. A long solid cylinder of length L_1 and radius R_1 falls coaxially under the attraction of gravity through a liquid within a concentric cylinder of length L_2 and radius R_2. It is known that $L_2 >> L_1$. Assume that the fluid is Newtonian and the flow is laminar and steady. No-slip condition is applied on the surface of the cylinders. The flow is fully

developed in the region between R_1 and R_2, which means that the end effect can be ignored.



(a) Derive the differential momentum balance in the z direction. (5%)

(b) Derive the fluid velocity profile in the region between R_1 and R_2. (4%)

(c) Derive the shear force acting on the solid cylinder. (3%)

(d) This setup can be designed as a **falling rod viscometer** by having a cylindrical vessel to be the outer cylinder. Then the solid cylinder of length L_1 and radius R_1 falls coaxially under the attraction of gravity through a liquid held within a concentric cylindrical vessel of length L_3 and radius R_2. It is known that only $L_3 > L_1$. Please describe how you can derive the fluid viscosity using this setup and write down the basic equation. (6%)

6. Deuterium was the material that scientists chose to fuel their attempted fusion reaction. When an electric current is run through the heavy water in a fusion cell, it triggers chemical reaction on the palladium electrode. The heavy water reacts with the electrons that make up the current to produce deuterium atoms and deuterium oxide ions:

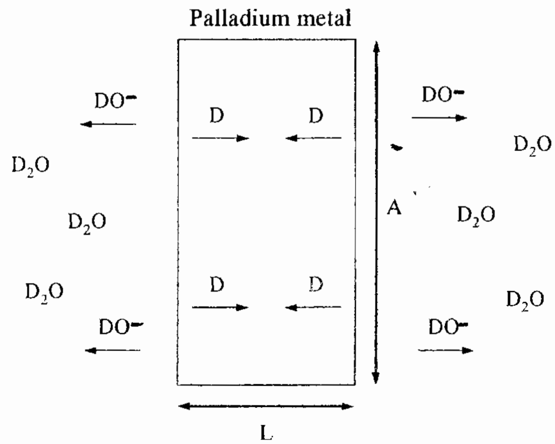
$$D_2O + e^- \rightarrow D + DO^-$$

(a) If the electrolysis is carried out at constant current and the electrode is in the form of a flat sheet with a thickness of L and interfacial area of A, derive the differential equation and boundary conditions for the concentration profile of deuterium atoms at various times. (10%)

(b) Solve the equation for the deuterium profile. (5%)

(c) What are the moles of deuterium atoms accumulated per time? (5%)

(Hint: Make any assumptions if necessary)



7. For calculating the ideal plates of a distillation column by using McCabe-Thiele Method, feed line was always used to construct the operation line of stripping section. Feed line is a function of thermal condition of the feed stream (**q**), defined as the moles of liquid to stripping section per mole of feed. Please derive the equation of feed line shown below, where x_F is the molar fraction of the feed. (10%)

Feed line: $$y = -\frac{q}{1-q}x + \frac{x_F}{1-q}$$

8. In a fractionation column, the flow rates of feed (F) and the distillate (D) are F=150, and D=80, (g-mole/min), respectively. The column is operated at reflux ratio of R_D=1.5. The feed is liquid at 30 °C. For the liquid feed, the boiling point (T_b) is 80 °C, the heat capacity (C_p) is 30 cal/gmol-°C, and the heat of vaporization is 7000 cal/gmol.
   (a). Please calculate the liquid and vapor flow rates in the rectifying (L, V) and stripping section ($\overline{V}, \overline{L}$). (assume constant molar flow) (6%)
   (b). If the reflux ratio, the input and output concentrations (X_D, X_B, X_F) are kept constant, but the feed is preheated to a saturated liquid, how about the effect of this action on the following parameters: (1) No. of ideal plate (2%); (2) the optimal feed plate (the top plate is the first plate) (2 %); (3) the amount of required cooling water (1%); (4) the required steam in the reboiler (1%); (5) the total energy required (1%); (6) In a factory, the feed was always pre-heated to the saturation state. Please explain the reason (2%). (describe your answer with the help of drawing figure if required)