國立中央大學100學年度碩士班考試入學試題卷

所別：化學工程與材料工程學系碩士班 甲組(一般生)　科目：輸送現象與單元操作　共 2 頁　第 1 頁

本科考試可使用計算器，廠牌、功能不拘　＊請在試卷答案卷（卡）內作答

This is a 100-min examination on Transport Phenomena and Unit Operations. There are six big questions in total and the perfect score is 100%. Please state your question numbers and steps clearly and underline your final answers in the given answer booklet.

1. For steady-state axial laminar flow of an incompressible liquid (with density ρ and viscosity μ) in an annulus region between two coaxial cylinders of radii κR (inner cylinder) and R (outer cylinder).
   (4%) (a) Please express the mean hydraulic radius of the annulus.
   (6%) (b) Also, please give an expression for the average velocity $\langle u_z \rangle$ in terms of the pressure difference (P_0-P_L).

2. An incompressible Newtonian fluid approaches a stationary cylinder with a uniform, steady velocity u_∞ in the positive x direction. When the equations of change are solved for creeping flow, the following expressions are found for the pressure and velocity in the immediate vicinity of the cylinder (they are not valid at large distances):

$$p(r,\theta) = p_\infty - C\mu\frac{u_\infty \cos\theta}{r} - \rho g r \sin\theta$$

$$u_r = Cu_\infty[\frac{1}{2}\ln(\frac{r}{R}) - \frac{1}{4} + \frac{1}{4}(\frac{R}{r})^2]\cos\theta$$

$$u_\theta = -Cu_\infty[\frac{1}{2}\ln(\frac{r}{R}) + \frac{1}{4} - \frac{1}{4}(\frac{R}{r})^2]\sin\theta$$

   Here p_∞ is the pressure far from the cylinder at y = 0 and

$$C = \frac{2}{\ln(7.4/\mathrm{Re})}$$

   with the Reynolds number defined as $\mathrm{Re} = 2Ru_\infty\rho/\mu$.
   (4%) (a) Use these results to get the pressure p, the shear stress $\tau_{r\theta}$, and the normal stress τ_{rr} at the surface of the cylinder.
   (8%) (b) Show that the x-component of the force per unit area exerted by the liquid on the cylinder is

$$-p|_{r=R}\cos\theta + \tau_{r\theta}|_{r=R}\sin\theta$$

   (8%) (c) Obtain the force $F_x = 2C\pi L\mu u_\infty$ exerted in the x direction on a length L of the cylinder.
   (5%) (d) What is the formula for the friction as a function of the Reynolds number?

   Hint:

$$\tau_{rr} = -\mu[2\frac{\partial u_r}{\partial r}] + (\frac{2}{3}\mu - \kappa)(\nabla\cdot u)$$

$$\tau_{r\theta} = -\mu[r\frac{\partial}{\partial r}(\frac{u_\theta}{r}) + \frac{1}{r}\frac{\partial u_r}{\partial \theta}]$$

3. There is a hollow cylinder with the length L, the inner radius r_0 and the outer radius r_1. The temperatures and heat conductivities at r_0 and r_1 are T_0, k_0 and T_1, k_1 respectively. The heat conductivity varies with temperature linearly.
   (10%) (a) Please derive the temperature distribution profile.
   (8%) (b) Please derive the heat flux.
   (5%) (c) If the thickness of the cylinder wall is extremely small, what will the heat flux be?

4. (3%) (a) Please explain the physical interpretation the Grashof number

$$\mathrm{Gr} = \frac{g\bar{\beta}(T_1 - T_0)l^3}{\nu^2}$$

(2%) (b) What dimensionless number is the product of Reynolds number and Prandtl number?

(2%) (c) And what is the physical interpretation of this dimensionless number of (b)?

5. (10%) Derive and explain why the operating-line equation with the overhead total condenser is a vertical line passing through the difference point on Ponchon diagram.

6. (25%) A beaker filled with an equimolar liquid mixture of ethyl alcohol and ethyl acetate evaporates at 0°C into still air at 101 kPa (1 atm) total pressure. Assuming Raoult's law applies, what will be the composition of the liquid remaining when half the original ethyl alcohol has evaporated? The following data are available.

	Vapor pressure, kPa at 0°C	Diffusivity in air, m^2/s
Ethyl acetate (AC)	3.23	6.45×10^{-6}
Ethyl alcohol (AL)	1.62	9.29×10^{-6}