

國立中央大學八十六學年度碩士班研究生入學試題卷

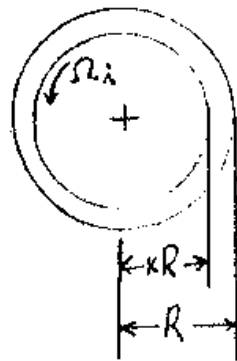
所別： 化學工程研究所 不分組 科目： 單元操作 共 2 頁 第 1 頁

1. If the air can be treated as an ideal gas, and the temperature of the atmosphere varies linearly with height above the earth,

$$T = T_0 - \alpha z$$

derive an expression for the pressure as a function of z , neglecting fluid motion in the atmosphere and the rotation of the earth. (15%)

2. A Stormer viscometer consists essentially of two concentric cylinders (length= L), the inner of which rotates with an angular velocity of Ω_i while the outer is held stationary. Viscosity (μ) is determined by measuring the rate of rotation of the inner cylinder under the application of a known torque (Γ). Develop an expression for the velocity distribution in this kind of apparatus, as a function of applied torque, for laminar flow of a Newtonian fluid. Neglect the end effects. (20%)



3. A steel tube ($k=50 \text{ W/m K}$) of inner and outer diameter $D_i = 20\text{mm}$ and $D_o = 26\text{mm}$, respectively, is used to transfer heat from hot gases flowing over the tube ($h_g = 200 \text{ W/m}^2 \cdot \text{K}$) to cold water flowing through the tube ($h_c = 8000 \text{ W/m}^2 \cdot \text{K}$). For radial conduction in a cylindrical wall, the heat transfer rate is $q = 2\pi Lk(T_o - T_i) / \ln(D_o / D_i)$.

- (a). What is the conduction resistance of the tube wall? (5分)
 (b). What is the cold side overall heat transfer coefficient U_c ? (10分)

4. Experimental results for heat transfer over a flat plate with an rough surface were found to be correlated by an expression of the form $Nu_x = 0.06 Re_x^{0.8} Pr^{1/3}$ where $Nu_x = h_x x / k$ is the local value of the Nusselt number at a position x measured from the leading edge of the plate.

- (a). Obtain an expression for the ratio of the average heat transfer coefficient \bar{h}_x to the local coefficient h_x . (8分)
 (b). For airflow at 50 m/s, what is the surface shear stress at $x = 1 \text{ m}$ from the leading edge of the plate? Estimate it by using the Reynolds analogy. (7分)
 properties of air (at 300 K): $\rho = 1.16 \text{ kg/m}^3$, $\nu = 15.89 \times 10^{-6} \text{ m}^2/\text{s}$, $Pr = 0.71$



5.(20%) **Diffusion method for separating helium from natural gas**

Helium may be separated from natural gas by diffusion method. The method is based on the fact that pyrex glass is almost impermeable to all gases but helium.

Suppose a natural-gas mixture containing helium is contained in a pyrex tube with dimensions shown in Fig. Problem. 5.

- (a) Write down a shell mass balance (or general differential equation) for this situation. (10%)
 (b) Obtain an expression for the rate at which helium will leak through the tube $\{W_{He}\}$ in terms of the diffusivity of helium in pyrex $\{D_{He-Pyr}\}$, the interfacial concentrations of the helium in the pyrex $\{c_{He,1}, c_{He,2}\}$, and the dimensions of the tube $\{R_1, R_2, L\}$. (10%)

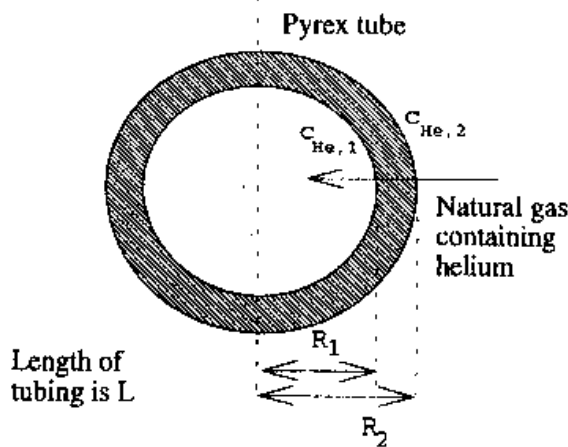


Fig. Problem 5

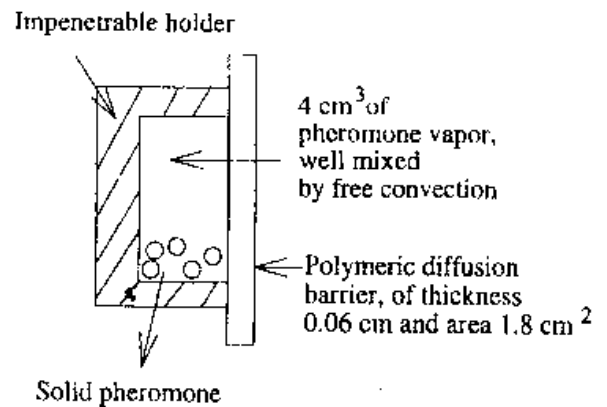


Fig. Problem 6

6.(15%) **Controlled release** is important in agriculture, especially for insect control. The pheromones are sex attractants released by insects. If you mix the attractant with an insecticide(殺蟲劑), you can wipe out all of one sex of a particular insect pest. A device for releasing one pheromone is shown schematically in Fig. Problem 6. This pheromone does not sublime(昇華) instantaneously, but a rate of

$$r_0 = 6 \times 10^{-17} [1 - 1.10 \times 10^7 (\text{cm}^3/\text{mol}) c_1] \text{ mol/sec}$$

where c_1 is the concentration in the vapor. The permeability of this material through polymer (DH) is $1.92 \times 10^{-12} \text{ cm}^2/\text{sec}$. Its concentration of pheromone outside of the device is essentially zero.

- (a) What is the concentration (mol/cm^3) of pheromone in the vapor? (10%)
 (b) How fast is the pheromone released by this device? (5%)

[Hint]:

- The permeability is defined as the product of the diffusivity (D) and solubility of pheromones (H) in the polymeric diffusion barrier
- At steady state the sublimation rate of pheromones inside the device is balanced by that of diffusion out of the device.