系所別：化學工程與材料工程學系 科目：輸送現象與單元操作

1. (5%) What is the definition of hydraulic radius? What is it used for?

2. (25%) Find the velocity profile and the average velocity of the isothermal flow of a power-law liquid down a vertical plate of length L and width W. The liquid film thickness is δ and the liquid density is ρ. (If you solve this problem for a Newtonian liquid instead, you will only get partial fractions of the points.)

3. (20%) A metal sphere of radius r_0 and thermal conductivity k is initially in equilibrium at $400°C$ in a furnace. It is suddenly removed from the furnace and cooling in air at $20°C$. The convection heat transfer coefficient for this cooling process is h.

(a) Write the conservation equation of the transient conduction occurs in the sphere.

(b) What are the initial condition and the boundary conditions of this system?

(c) Under what physical condition the temperature in the sphere can be regarded as uniform?

(d) Write the approximate energy balance equation for the transient conduction in this solid sphere if the lumped capacitance method can be applied.

4. (15%) A thin-walled concentric tube heat exchanger is to be used to cool engine oil from 160 to $60°C$, and water, which is available at $25°C$, is to be used as the coolant. The oil and water rates are each 2 kg/s, and the diameter of the inner tube is $0.5m$. The corresponding value of the overall heat transfer coefficient is $250 W/m^2.K$.

(a) Determine the total heat transfer of this heat exchanger.

(b) Determine the log mean temperature difference of this system.

(c) How long must the heat exchanger be to accomplish the desired cooling?

Properties:

engine oil ($\overline{T}_h = 110°C$) : $c_p = 2260 J/kg.K$.

water ($\overline{T}_c = 50°C$) : $c_p = 4182 J/kg.K$

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. This method presumably offers possibility for more efficient and less costly separations than the previous method of low-temperature distillation.

(a) Write down a shell mass balance (or general differential equation) for this situation. (5%)

(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 $\{D_{He\text{-}Pyr}\}$, 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%)

(c) If $(R_2 - R_1)/R_1 << 1$, W_{He} can be simplified and explain its physical meaning. (5%)

[Hint: $\ln(1+x) \cong x$ if $x<<1$.]

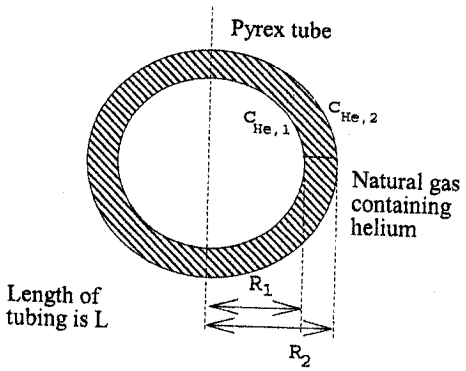
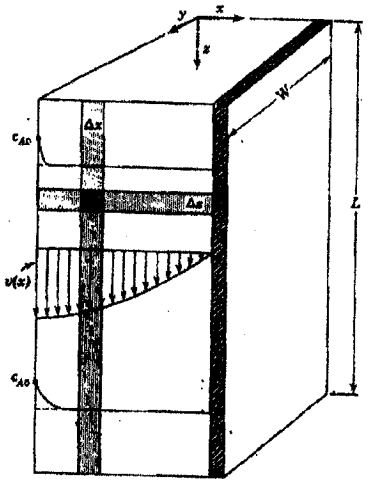


Fig. Problem 5



Absorption into a falling film.

參考用

6. (15%) **Steady diffusion into a falling liquid film**

Consider the absorption of gas A by a laminar falling film of liquid B. The material A is only slightly soluble in B, so that the viscosity of the liquids is not changed appreciably. We shall make the further restriction that the diffusion take place so slowly in the liquid film that A will not "penetrate" very far into B -- that the penetration distance δ be small in comparison with the film thickness. The characteristic penetration distance δ varies with z. The velocity of liquid B within the penetration distance can hence be regarded as v_{max}. The system is sketched in Fig. Problem 6.

(a) Write down the governing equation and the boundary conditions. (5%)

(b) Estimate the local mass flux N_{Az} at the surface $x = 0$ at a position z down the plate and the total moles of A w_A transferred per unit time from the gas to the liquid film, which has length L and width W. (10%)