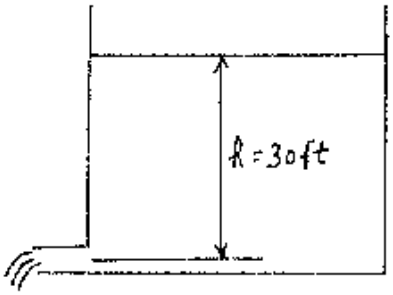
1. Prove that the flow of a liquid in laminar flow between infinite parallel flat plates is given by

$$p_a - p_b = (12\mu VL)/(\beta^2 g_c)$$

where V = average velocity
L = length of plate in direction of flow
ß = distance between plates
p = pressure

Neglect end effects (15%).

2. (a) The tank in the following figure is full of water and open at the top. There is a hole near the bottom, the diameter of which is small compared with the diameter of the tank. What is the velocity of the flow out the hole? (b) Repeat (a), making the area of the outlet hole 1 ft^2 and the cross-sectional area of the tank 4 ft^2. **(Hint: For part (b), you cannot assume that the velocity at the free surface is zero)** (20%).



參考用

3. A spherical, thin walled metallic container is used to store liquid nitrogen at 77 K. The container has a diameter of 0.5 m and is covered with an evacuated, reflective insulation composed of silica powder (conductivity k = 0.0017 W/m · K.) The insulation is 25 mm thick, and its outer surface is exposed to ambient air at 300 K. The convection coefficient is known to be 20 W/m^2 K. The latent heat of vaporization of liquid nitrogen is $2x10^5$ J/kg.
(a). From Fourier's law, derive and calculate the conduction resistance of the insulation layer. (15%)
(b). Calculate the convection resistance of ambient air. (5%)
(c). What is the rate of heat transfer to the liquid nitrogen? (5%)
(d). Estemate the loss of liquid nitrogen per day. (5%)

4. Diffusion Coefficients of Gases and Liquids (10%)
(a). Write down the order of magnitude of the diffusivity (cm^2/sec) in gases at one atmosphere and that in liquids at 25°C ? (6%)
(b). Estimate the range of the Schmidt number for both gases and liquids ? (4%)

Hint:

1. Take a guess !!
2. The Schmidt number is defined as

$$Sc = \nu/D$$

where $\nu = \mu/\rho$ is the kinematic viscosity and D the diffusivity.

5. Diffusion and First-Order Chemical Reaction Inside a Porous Catalyst. (25%)
The elementary isomerization reaction

A --> B

is taking place inside a porous catalyst. The reaction is first order, $r_A = -kc$. If the particle has a slab geometry, set up the coordinate frame with the origin being at the center of the particle.

(a). Write the differential mass balance for the reactant. (10%)

(b). Derive an expression for the concentration profile c(z). (5%)

(c). Express the effectiveness factor η in terms of the Thiele modulus ϕ. (10%)

Hint:

1. The boundary conditions for the above mass balance equation are
   $c = c_0$; at $z = R$ (surface concentration)
   $dc/dz = 0$; at $z = 0$ (symmetry)
2. The effectiveness factor is defined as
   η = (actual reaction rate within the catalyst)/
   (rate if not slowed by diffusion)
   $\eta = -D(dc/dz)_{z=R} / kc_0 = f(\phi)$
   where $\phi = R(k/D)^{1/2}$.
3. D = the diffusivity of A inside the catalyst.
   k = the rate constant of the first order reaction.
   R = the size of the slab catalyst.

參考用

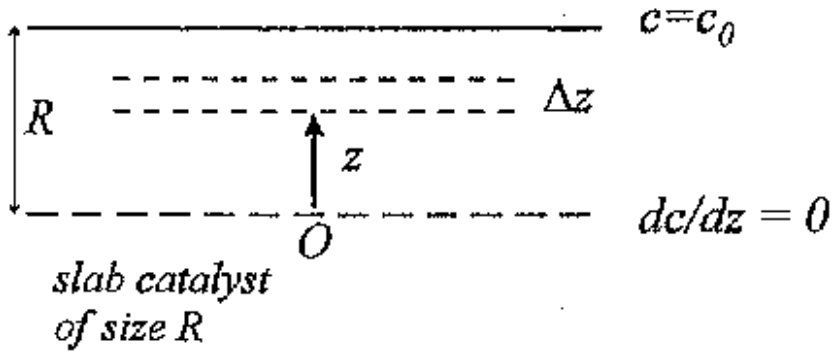


Fig. P5