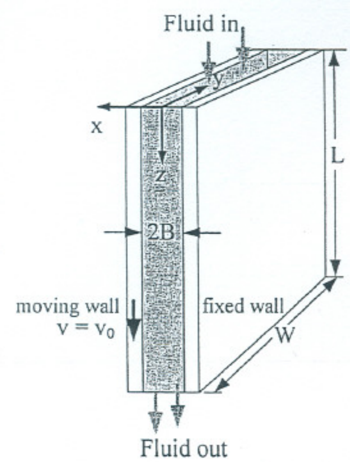
1. (20%) Define and interpret the followings:
   (a) Navier-Stokes equation (5%)
   (b) Skin-friction drag and form drag around a sphere (5%)
   (c) Knudsen diffusion (5%)
   (d) Prandtl number and Schmidt number (5%)

2. (30%) Couette flow is the laminar flow of a viscous fluid in the space between two parallel plates, one of which is moving relative to the other. A laminar flow of a Newtonian fluid (constant ρ and μ) is in a thin slit formed by two parallel walls of length L and width W with a distance 2B apart (B<<W<<L), the wall at x = B is moving in the positive z direction at a steady speed v_0. The pressure drop and the gravity force need consideration in this case and the edge effects can be neglected.



   (a) Show the shear-stress distribution. (10%)
   (b) Determine the velocity profile. (5%)

   Now, if the two walls are stationary, the simplified case for the fluid flowing in a narrow slit is considered.
   (c) Show the slit analog of Hagen-Poiseuille equation. (5%)
   (d) Express the friction factor as a function of the Reynolds number for the laminar flow in a thin slit. (10%)

3. (25%) 900 W/m^3 of heat is generated within a 10-cm-diameter nickel-steel sphere for which k= 12 W/m℃. The environment is at 25℃ and there is a natural convection heat transfer coefficient of 10 W/m^2℃ around the outside of the sphere. What is its center temperature at steady state?

   Hint：
$$\nabla^2 T = \frac{1}{r}\frac{\partial^2 (rT)}{\partial r^2} + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial\theta}(\sin\theta\frac{\partial T}{\partial\theta}) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 T}{\partial\phi^2}$$

4. (25%) Gas A diffuses through a gas film to the surface of a cylindrical catalyst particle (radius= R) where it undergoes the reaction $2A \xrightarrow{k_1} B$. Gas B then diffuses from the catalyst surface and is swept away.
   (a) Neglecting diffusion and reaction on the ends of the particle, derive an expression for concentration profile of A in stagnant film surrounding the cylinder for a slow first-order reaction. (15%)
   (b) Obtain an expression for the molar flux of B. Assume that the thickness of the gas film is δR and $y_A = y_{A\delta}$. (10%)