1. (35%)

(a) (3%) Write down the definition of the fanning friction factor for flow in conduits.

(b) (8%) Assume that a Newtonian fluid with a constant density ρ and constant viscosity μ flows at an unknown rate u_1 through a horizontal steel pipe having a length L and diameter D; please derive a formula that gives the fanning friction factor in terms of ρ, μ, L, D, and ΔP under a pressure difference ΔP. Also derive the formula for the friction factor as a function of the Reynolds number in laminar flow.

(c) (8%) What pressure difference is required to cause the liquid (having a density of 875 kg/m^3 and μ=1.13×10^{-3} Pa·s) to flow at a volumetric rate 1.066×10^{-6} m^3/s in a horizontal, smooth, circular tube with an inside diameter of 2.22×10^{-3} m and a length 0.317 m?

(d) (8%) The Newtonian fluid is flowing at an unknown velocity u_1 through a horizontal pipe of cross-sectional area A_1 at a pressure p_1, and then it passes to a section of the pipe in which the area is reduced gradually to A_2, and the pressure is p_2. Assuming no friction losses, calculate the velocities u_1 and u_2 if the pressure difference (p_1-p_2) is measured.

(e) (8%) A mechanical-energy loss should be considered, however, when the fluid flows from a small pipe to a large pipe through an abrupt expansion. Calculate the velocities u_1 and u_2 if the pressure difference (p_1-p_2) is measured.

2. (20%)

A heated sphere of radius R is suspended in a large, motionless body of fluid. It is desired to study the heat conduction in the fluid surrounding the sphere in the absence of convection. The surface temperature of sphere is T_R, the temperature of infinite fluid is T_∞, and k is the thermal conductivity of fluid.

(a) (12%) Determine the temperature distribution of fluid.

(b) (5%) Find the relationship for predicting the Nusselt number.

(c) (3%) In what respect are the Biot number and the Nusselt number different?

3. (10%)

The empirical equation of the friction factor for turbulent flow in smooth tubes is

$$f/2 = 0.023\,\mathrm{Re}^{-0.2}$$

The Colburn j factor for heat transfer is defined as

$$j_H = (h/\rho v c_p)\mathrm{Pr}^{2/3}$$

and the Colburn j factor for mass transfer is defined as

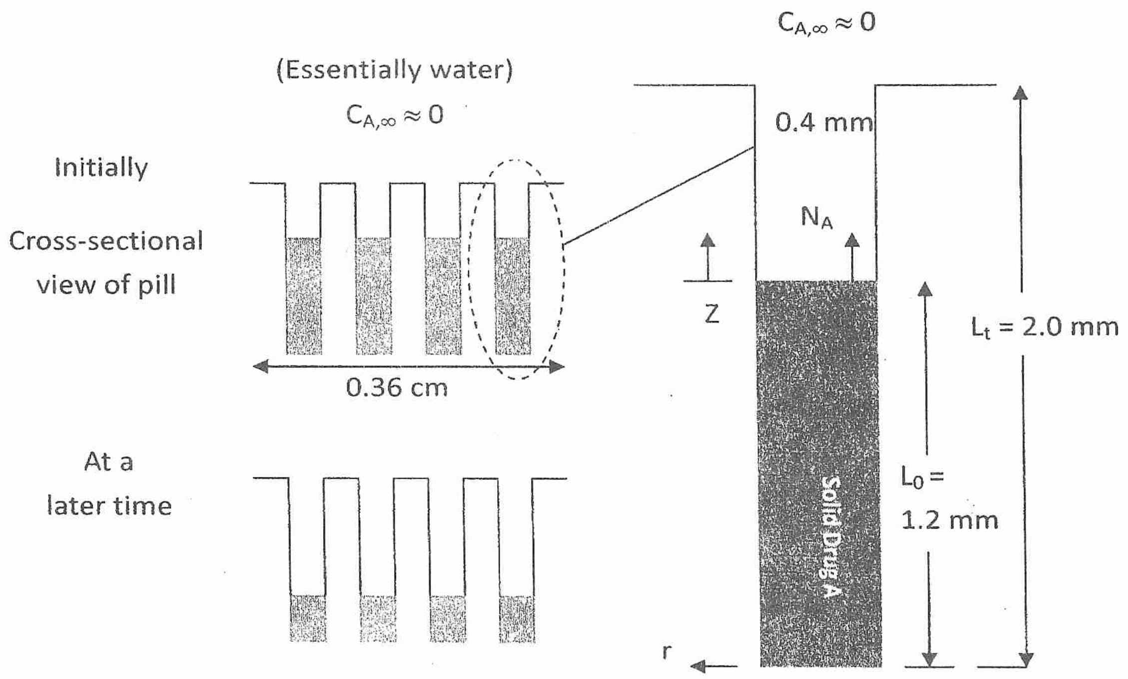
$$j_D = (k_c/v)Sc^{2/3}$$

Here v is the characteristic velocity. Find the equations for predicting the Nusselt number and the Sherwood number.

注意：背面有試題

4. (35%)

Consider the timed drug-release pill illustrated below.



The pill is ingested into the stomach. The pill is a slab, 0.36 cm per side, that has an array of 16 cylindrical pores in it. Each pore is 0.4 mm in diameter and 2.0 mm deep. Pure solid drug A is loaded into each pore to a depth of 1.2 mm, which provides a total initial drug loading of 2.65 mg in all of the pores. The density of the solid drug A is 1.10 g/cm^3. The drug dissolves into the fluid inside the stomach, which approximates the properties of water (component B). The maximum solubility of drug A in water is 2.0×10^{-5} cm^2/s at body temperature of 37°C. The molecular weight of the drug is 120 g/mol.

(a) (10%) Starting with the general differential equation for mass transfer and Fick's flux equation, develop a simple model, in final integrated form, for predicting the flux of the drug from one pore. You may assume that the diffusion process is pseudo-steady state, the stomach fluid serves as an infinite sink for the drug so that c_A = 0, and the drug does not chemically degrade inside the pore.

(b) (10%) From your model, determine the total transfer rate of the drug from the whole pill, W_A, to the body when each 0.2 cm pore is filled to a depth of 0.12 cm with solid drug.

(c) (15%) How many hours will it take for all of the drug to be released?

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