科目	輸送現象及單元操作	適用系所	化學工程學系	時間	100 分鐘

※請務必在答案卷作答區內作答。

1. **(30%)** Find the hydraulic radius for each of the following: (1) an equilateral triangular pipe (side = *a*); (2) a square pipe (side = *a*); (3) an annular pipe (outside diameter = *Do*; inside diameter *Di*); (4) an open semi-circular pipe (diameter = *D*); (5) a closed semi-circular pipe (diameter = *D*); (6) a circular pipe (diameter = *D*) without the inscribed equilateral triangle.

2. **(20%)** A substance *A* diffuses to a catalyst surface where it is instantaneously polymerized following the reaction: $nA \rightarrow An$. Find the expression for the molar flux N_{Az} through an imaginary gas film of *A* in terms of mole fraction y_{A0} at the surface, total concentration *C*, gas film thickness δ, stoichiometric number *n*, and the diffusion coefficient D_{AB}.

3. An oddly shaped object is to be used to transfer species A into gas B. The flow velocity, *u*, of B is 20 m/s. Find the mass transfer coefficient, k_c, and the thermal conductivity, *k*, for the system, if given an empirical equation for heat transfer between flowing B and the object. Regarding B, assume C_p = 1000 J/kg K, Pr = 0.8, $\mu = 2 * 10^{-5}$ kg/m s, ρ = 1.2 kg/m^3, and $D_{AB} = 2.5 * 10^{-5}$ m^2/s.

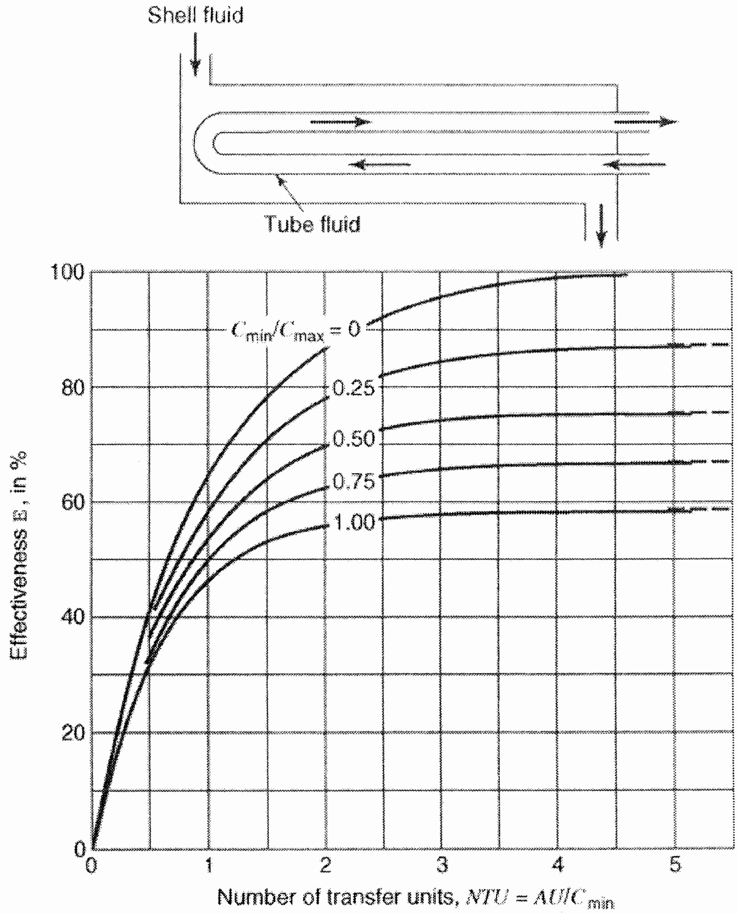
$$h = 30\, G^{0.55} \text{ where } G = \text{mass flux} = \rho * u \; [kg/m^2\, s].$$

$$j_h = \frac{h}{\rho C_p u} Pr^{2/3}.$$

$$j_d = \frac{k_c}{u} Sc^{2/3}.$$

(25%)

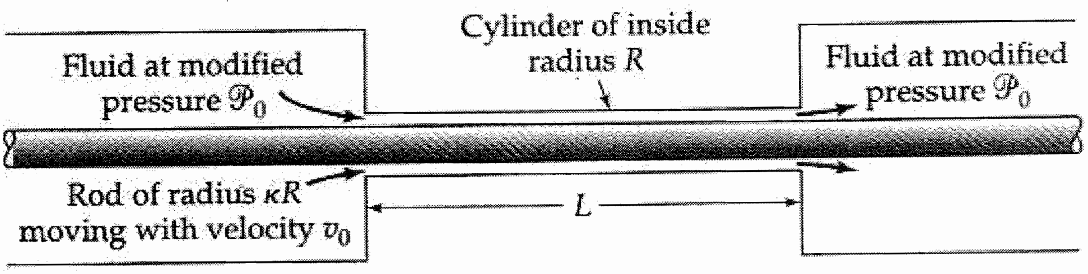
4. **(30%)** Water flowing at a rate of 10 kg/s (Cp = 4181 J/kg·K) through 50 tubes in a double-pass shell-and-tube heat exchanger heats air that flows on the shell side. The tubes are made of brass with outside diameters of 2.6 cm and are 6.7 m long. Surface coefficients on the inside and outside tube surfaces are 470 and 210 W/m^2·K, respectively. Ignore the thermal resistance of bass in your calculation of the overall heat transfer coefficient U. Air enters the unit at 298 K with a flowrate of 16 kg/s (Cp = 1007 J/kg·K). The entering water temperature is 350 K. Determine
(10%) (a). the heat exchanger effectiveness
(10%) (b). heat transfer rate to air
(10%) (c). exit temperature of water and air streams.



(c)

Heat exchanger effectiveness for one shell pass and two and a multiple of two tube passes.

5. A cylindrical rod of radius κR moves axially with velocity υ_0 along the axis of a cylindrical cavity of radius R as seen in the figure. The pressure of both ends of the cavity is the same, so that the fluid moves through the annular region solely because of the rod motion. The Navier-Stokes equation in the cylindrical direction is listed below. **(45%)**



$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + v_z\frac{\partial v_r}{\partial z} - \frac{v_\theta^2}{r}\right) = -\frac{\partial p}{\partial r} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_r)\right) + \frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2} + \frac{\partial^2 v_r}{\partial z^2} - \frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}\right] + \rho g_r$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + v_z\frac{\partial v_\theta}{\partial z} + \frac{v_r v_\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_\theta)\right) + \frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2} + \frac{\partial^2 v_\theta}{\partial z^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \theta}\right] + \rho g_\theta$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z$$

(30%) (a). Calculate the velocity distribution in the narrow annular section.

(15%) (b). Find the force (Fz) requied to maintain the motion of the rod.