淡江大學九十二學年度碩士班招生考試試題

系別：化學工程與材料工程學系　　科目：輸送現象與單元操作

准帶項目請打「○」否則打「×」
○　簡單型計算機

本試題共 2 頁

本試題雙面印製

1. Water having density of 998 kg/m^3 is flowing in a channel with a rectangular cross section as shown in Fig. 1. The rectangular cross section has width of 0.15 m and height of 0.1 m. The viscosity of water is 0.0089 kg/m-s. Calculate the Reynolds number (Re) in the channel when the water volume flow rate is (a) 5.4 m^3/hr and (b) 21.6 m^3/hr. (20%)

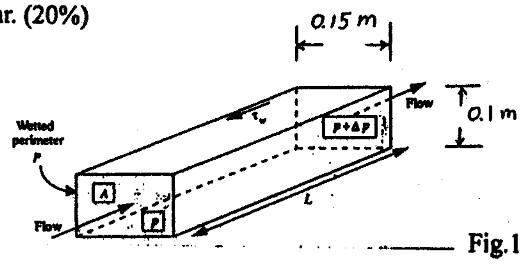

Fig.1

2. Water (density(ρ)= 998 kg/m^3, viscosity =0.0089 kg/m-s) is flowing in an inclined pipe as shown in Fig. 2. The pipe length (L) is 50 m and inner diameter (D) is 0.12 m, and the inclination angle (θ) is 30°. The wall shear stress (τ_W) is related to the Fanning friction factor (f_F) in form of $\tau_W = f_F \rho u_m^2/2$, where u_m is the flow velocity. The roughness of the pipe is 0.0046 mm. Calculate the pressure drop ($p_1 - p_2$) when the water flow rate is (a) 3.6 m^3/hr and (b) 21.6 m^3/hr. The friction factor plot is shown as Fig. 3. (20%)

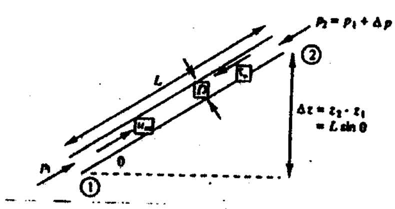

Fig.2

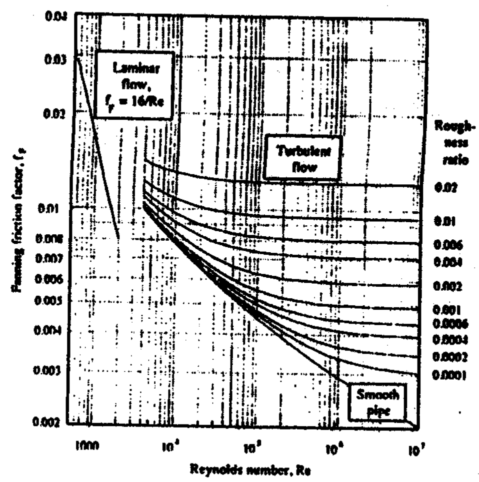

Fig. 3

3. Radial heat transfer is occurring by conduction through a long hollow cylinder of length L with the ends insulated.

(a) What is the final differential equation for steady-state conduction? The cylinder has a constant thermal conductivity. (5%)

(b) Solve the equation for the temperature profile from part (a) for the boundary conditions given as follows: $T = T_i$ for $r = r_i$, $T = T_o$ for $r = r_o$. (10%)

(c) Using part (b), derive an expression for the heat flow q. (5%)

Note: The equation of energy change in cylindrical coordinates is

$$\left(\frac{\partial T}{\partial t} + v_r \frac{\partial T}{\partial r} + \frac{v_\theta}{r}\frac{\partial T}{\partial \theta} + v_z \frac{\partial T}{\partial z}\right) = \alpha\left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{1}{r^2}\frac{\partial^2 T}{\partial \theta^2} + \frac{\partial^2 T}{\partial z^2}\right)$$

P1-2

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4. A drop of liquid toluene is kept at a uniform temperature of 26°C and is suspended in the air by a fine wire. The initial radius r_1 = 2.0 mm. The vapor pressure of toluene at 26°C is p_{A1} = 3.85 kPa and the total pressure is P = 101.325 kPa. The density of the liquid toluene (ρ_A) is 866 kg/m^3 and the molecular weight of toluene (M_A) is 92 kg/kgmole. The gas constant R is 8314 m^3-Pa/kgmole-K.

(a) Derive the following equation to relate the diffusivity D_{AB} and the time t_F for the drop to evaporate completely in a large volume of still air.

$$t_F = \frac{\rho_A r_1^2 RT p_{BM}}{2M_A D_{AB} P(p_{A1} - p_{A2})}$$

where p_{A2} is the partial pressure of toluene at a distance r_2 far from the liquid drop, and $p_{BM} = (p_{A1} - p_{A2})/\ln[(P - p_{A2})/(P - p_{A1})]$. (15%)

(b) Calculate the value of D_{AB} in unit of m^2/s, if the time t_F for complete evaporation is 1400 seconds. (5%)

5. A single-effect evaporator is used for concentrating a feed of 9000 kg/h of a 10 wt% aqueous solution of NaOH to a product of 40 wt% NaOH solution. The feed enters the evaporator at 20 °C. The pressure in the vapor space of the evaporator is 11.7 kPa and the pressure of the saturated steam used is 172.2 kPa. The overall heat-transfer coefficient is 1988 W/m^2-K. Calculate the steam used, the steam economy in kg vaporized/kg steam, and the heating area. (20%)

The boiling point of pure water at 11.7 kPa is 48.9 °C, and the enthalpy of saturated vapor at this temperature is 2590 kJ/kg. The heat capacity of the superheated steam is 1.884 kJ/kg-K. For the saturated steam at 172.2 kPa, the temperature is 115.6 °C and the latent heat is 2214 kJ/kg. The enthalpy of feed at 20 °C is 70 kJ/kg, and the enthalpy of the product (40 wt% NaOH solution) can be calculated using following equation: h = 70 + 5.2(T-20), where T(°C) is the temperature of the product and h(kJ/kg) is the enthalpy. The boiling-point rise chart for system NaOH-water is shown in Fig. 4. The reference state of the enthalpy is liquid water at 0 °C.

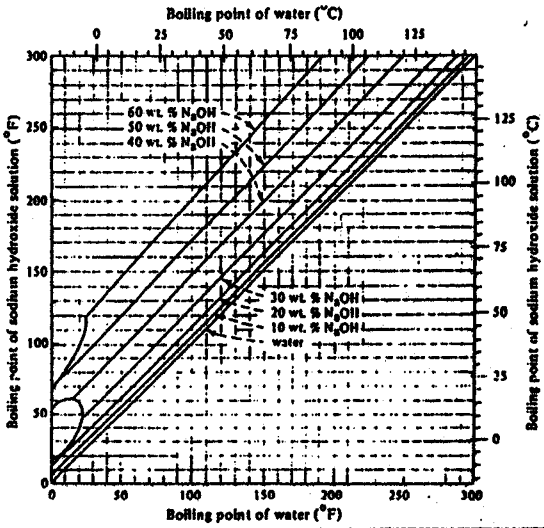

Fig. 4