國立成功大學

111學年度碩士班招生考試試題

編　號：74

系　所：化學工程學系

科　目：單元操作與輸送現象

日　期：0219

節　次：第 1 節

備　註：可使用計算機

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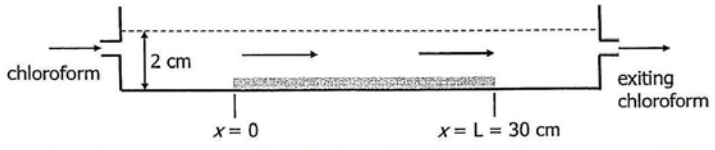
※ 考生請注意：本試題可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. A pump is used to extract water (density = 1000 kg/m^3) from a reservoir in which the pressure is 101300 Pa. The required flow rate of water is 300 m^3/h. The vapor pressure of water is 3200 Pa, and the viscosity of water is 1.30 mN-s/m^2. A concrete pipe (inner diameter = 6 inches) was placed vertically all the way down from the reservoir to the pump along with two 90° elbows at both ends. The Fanning friction factor of the pipe was estimated as 0.012, and the head loss of each elbow is 0.1 m. If the required NPSH (NPSHR) of the pump is 15 m, what should be the minimum pipe length, namely, the height of the reservoir above the pump, in order to reach the sufficient available NPSH (20%)?

2. Derive the relationship between the average velocity and maximum velocity within a smooth circular pipe flowing with a turbulent flow, which follows Prandtl's 1/7 power law. (10%)

3. Chloroform is used to remove a polystyrene (PS) film from a nonporous flat surface of length 30 cm and width 8 cm. Initially, the thickness of the PS film is 0.02 cm. The PS film is placed in an open flat pan of length 40 cm and width of 10 cm. Subsequently, chloroform at a volumetric flow rate of 20 cm^3/s is added to the pan, and the depth of chloroform in the pan is maintained at 2.0 cm. It is assumed that the concentration of dissolved PS in bulk chloroform is essentially zero. It is also assumed that the change in film thickness during the dissolution process does not affect the convection mass-transfer process.
   (a) What are the Schmidt number and the average Sherwood number for the mass-transfer process? (6%)
   (b) What is the average flux of dissolved PS from the surface? (4%)
   (c) Develop a relationship between the local convective mass-transfer coefficient ($k_{c,x}$) and film position (x). (4%)
   (d) Eventually, the PS film will completely dissolve away from the flat surface. However, before this time the thickness of the PS film remaining on the flat surface will not be uniform. Find the change in PS film thickness (l) with regard to the film position and time (t). (3%)
   (e) What are the hydrodynamic (δ) and concentration boundary-layer (δ_c) thicknesses at x = 15 cm? (3%)
   Additional information:
   Diffusion coefficient of dissolved PS in chloroform: 2.0 × 10^{-6} cm^2/s;
   Mass density of PS: 1.0 g/cm^3; mass density of chloroform: 1.5 g/cm^3;
   Kinematic viscosity of chloroform: 6.0 × 10^{-3} cm^2/s;
   Maximum solubility of dissolved PS in chloroform: 0.05 g/cm^3.

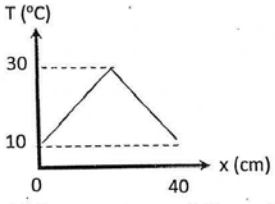


4. A continuous fractionating column was designed to separate 1,000 kg-mole/h of a mixture of 30% benzene and 70% toluene into an overhead product containing 98% benzene and a bottom product containing 90% toluene. The feed has a boiling point of 97 °C. The molar latent heats of benzene and toluene are 7,500 and 8050 cal/g-mol, respectively. The feed is liquid with a temperature of 40 °C (specific heat 38.6 cal/g-mole.°C; latent heat:7885 cal/mol); and the vapor flow rate in the rectifying section (V) is 753 kg-mole/h，Please answer the following question.
   (a). What are the flow rates of overhead product and bottom product per hour. (3%)
   (b). What is the reflux ratio R_D? (3%)
   (c). Please calculate the vapor and liquid flow rates in the striping section. ($\overline{V}$ $\overline{L}$) (4 %)
   (d). What is the heat required in the re-boiler; (3%)
   (e). If the feed is a saturated liquid, what is the heat must be removed in the condenser. (2%)
   (f). If the feed is a saturated vapor, what is the reflux ratio. (2%)
   (g). For the conditions of problem (c), the toluene concentration in the bottom product should be increased to 98%, how many ideal stage are required for this concentration increase. The equilibrium concentration between benzene (x) and toluene (y) is (y=2x). (8%)

$$N = \frac{\ln[(y_a - y_a^*)/(y_b - y_b^*)]}{\ln[(y_b^* - y_a^*)/(y_b - y_a)]}$$

5. A laterally insulated bar with 40 cm in length has an initial temperature as follows:

$$T(x) = \begin{cases} x + 10, & if \quad 0 < x < 20 \\ 50 - x, & if \quad 20 < x < 40 \end{cases}$$



   Sketch the temperature profile when t → ∞ if
   (a) both ends are kept at temperature 10 °C (5%)
   (b) both ends are insulated (5%)
   (c) one end is kept at 20 °C and the other at 100 °C with an initial temperature as follows: (5%)

$$T(x) = \begin{cases} 6x + 20, & if \quad 0 < x < 20 \\ -2x + 180, & if \quad 20 < x < 40 \end{cases}$$

6. Water flows in a circular, thin-walled tube with 100 mm in diameter and 10 m in length. The flow rate is 0.5 kg/s and the inlet and outlet temperatures are 20 and 60 °C, respectively. The steam serves as the heating source, which condenses at the outer surface of the tube at 120 °C.
   (a) What is the logarithmic-mean temperature difference? (5%)
   (b) Find the average convective heat-transfer coefficient. (5%)
   Note: the specific heat of water is 4178 J/kg.K