國立成功大學
112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：0206

節　次：第 1 節

備　註：可使用計算機

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考試科目：單元操作與輸送現象　　考試日期：0206，節次：1

※ 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 rectangular flatboat is moving in a lake on the x direction with a constant speed of 15 m/s. A *laminar boundary layer* is formed at the interface between the bottom side of the flatboat and water. The front edge of the flatboat is defined as the leading edge, the length of the flatboat on the x direction is 3 m, and the width of the flatboat (on the z direction) is 1.5 m. Density (ρ) and viscosity (μ) of water are 1000 kg/m^3 and 1.30 mN-s/m^2, respectively. The von Kármán approximation shown below is used in order to estimate the shear force between the flatboat and water,

$$\frac{\tau_0}{\rho} = \left(\frac{d}{dx} v_\infty\right) \int_0^\delta (v_\infty - v_x)\, dy + \frac{d}{dx} \int_0^\delta v_x (v_\infty - v_x)\, dy$$

   (a) By guessing that the velocity profile in the boundary layer is $v_x = \alpha + \beta y + \gamma y^2$, find the **velocity profile (v_x)** as the function of boundary layer thickness (δ), y, and v_∞. (4%)
   (b) Derive the **expression of δ** as the function of x, μ, ρ and v_∞. (6%)
   (c) Based on the result from (b), calculate the overall shear force between the flatboat and water. (5%)

2. Glycerol, which has a density of 1260 kg/m^3 and a viscosity of 50 mN-s/m^2, is flowing in a circular pipe (d = 40 mm). An orifice meter (d = 24 mm) is used here to monitor the flow rate of the glycerol. One day a problem showed up in this process, and you suspected that the problem may be attributed to the broken orifice meter. To test this hypothesis, you inserted a pitot tube at the center (r = 0) of the pipe, and you found that the pressure reading of the pitot tube is 2100 Pa. The orifice meter is now showing a pressure reading of 450 Pa.
   (a) According to the pitot tube measurement, what is the measured velocity at r = 0? (2%)
   (b) According to the pitot tube measurement, what are the average velocity of the flow in the pipe, the corresponding Reynolds number, and the mass flow rate of the glycerol, respectively? (4%)
   (c) Based on the reading of pitot tube and the reading of orifice, calculate the discharge coefficient of the orifice. Is the orifice meter broken? (9%)

3. For a laminar flow past a flat surface, please comment on the hydrodynamic boundary layer and thermal boundary about which one is thicker at what condition. (3%)

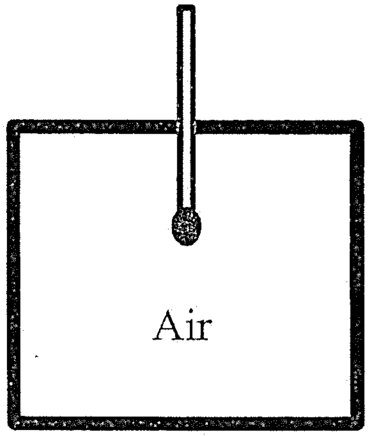
4. A black thermocouple having the bead with 2 mm in diameter is initially at room temperature (25 °C) and suddenly placed in a black box (15×15×15 cm) filled with 125 °C air as shown in the following. The heat transfer coefficient is 400 W/m^2.K. The thermal conductivity (κ), density (ρ) and specific heat (C) of the bead are 100 W/m.K, 10000 kg/m^3, and 300 J/kg.K, respectively.
   (a) If thermal radiation is neglected, can the lumped-parameter analysis be applied such that the temperature of the air is measured by the thermocouple? Why? (3%)

(b) Derive the temperature of the bead as a function of time. (7%)

(c) How much time does it take to reach 123 °C? (2%)

(d) If the conductivity of the bead changes to 1 W/m.K, write down the governing equation of the bead temperature and its initial and boundary conditions. (4%)

(e) If the wall temperature of the black box is 600 °C and the system is steady, what temperature will the thermocouple read? (neglect the radiation between thermocouple and air. The Stefan-Boltzmann constant: $5.676*10^{-8}$ W/m^2.K^4) (6%) (*hint: heat convected is balanced by the radiation of hot wall*)



5. Methylene chloride (species *A*) undergoes an interphase convective mass-transfer process between air and water at 20 °C and 1.80 atm total pressure. Air is the inert carrier gas, and water is the inert solvent. In the present process, the mole fractions of methylene chloride are 0.100 and 0.006 in the gas and liquid phases, respectively. The mass-transfer coefficients for methylene chloride are $k_y = 0.008$ gmol/m^2·s and $k_x = 0.150$ gmol/m^2·s for the gas and liquid films, respectively. At 20 °C, the density of liquid water is 992.3 kg/m^3.

(a) What is the process? (2%)

(b) Determine the Henry's law constant (H) for methylene chloride dissolved in water, according to the definition $p_A = Hc_A$, where p_A and c_A are the partial pressure of methylene chloride in air and concentration of methylene chloride dissolved in water, respectively. (4%)

(c) Determine the overall coefficient K_L. (4%)

(d) What is the flux of methylene chloride across the gas and liquid phase? (4%)

(e) Determine the interface mole fraction, $y_{A,i}$ and $x_{A,i}$. (6%)

Equilibrium data for the methylene chloride-air-water system at 20 °C and 1.80 atm are given in the table below.

y_A	0.10	0.15	0.20	0.25	0.30
x_A	0.00250	0.00375	0.00500	0.00625	0.00750

y_A: mole fraction of methylene chloride in air

x_A: mole fraction of methylene chloride dissolved in water

6. In operation of a continuous fractionation column, two phenomena appear around the top plate: (i) accumulation and flooding of the liquid, (ii) gradual decrease in the temperature of the top plate. What is the reason leading to these phenomena? and how to solve it? (5%)

7. A mixture contains 50 wt% acetic acid, 40 wt% isopropanol ether and 10 wt% water. Pure water is used as the solvent to extract acetic acid from the solution. The phase diagram of the three compounds is shown below. Please answer the following problems,
   (a) To perform the extraction, what is the minimum water required per 100 g of mixture. (6%)
   (b) If the water input is 100 g per 100 g of the mixture, what are the compositions of the extract phase and raffinate phases after extraction? (7%)
   (c) What is the mass of acetic acid extracted? (7%)
   (Please explain your answer by drawing a simple figure on your answer sheet.)