國立中正大學
114學年度碩士班招生考試
試 題
[第3節]

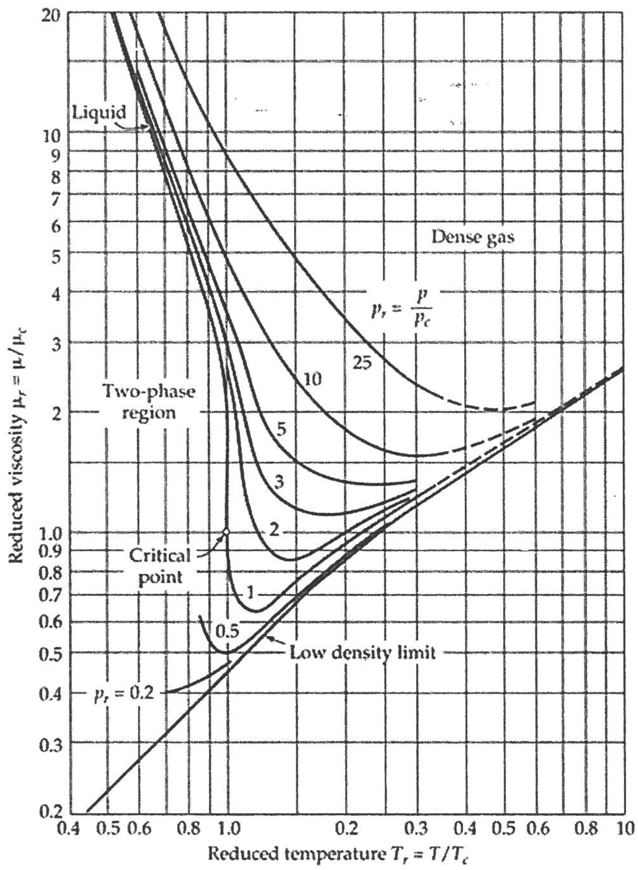
科目名稱	輸送現象與單元操作
系所組別	化學工程學系

—作答注意事項—

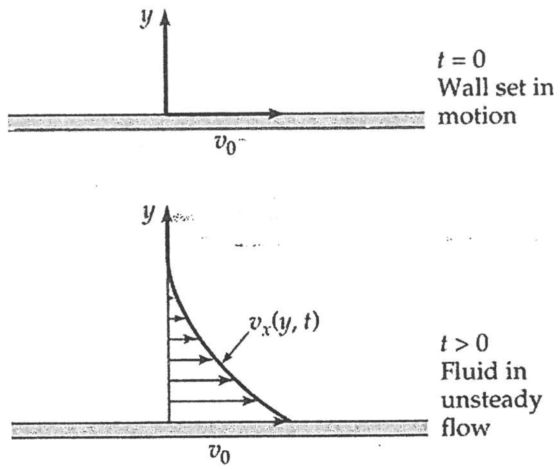
※作答前請先核對「試題」、「試卷」與「准考證」之系所組別、科目名稱是否相符。

1. 預備鈴響時即可入場，但至考試開始鈴響前，不得翻閱試題，並不得書寫、畫記、作答。
2. 考試開始鈴響時，即可開始作答；考試結束鈴響畢，應即停止作答。
3. 入場後於考試開始40分鐘內不得離場。
4. 全部答題均須在試卷（答案卷）作答區內完成。
5. 試卷作答限用藍色或黑色筆（含鉛筆）書寫。
6. 試題須隨試卷繳還。

1. The chart below shows reduced viscosity as a function of reduced temperature.
   i) Explain why reduced properties are commonly used in engineering and scientific analyses. **(5 points)**
   ii) Discuss why the viscosity of liquids decreases, while the viscosity of gases increases, with an increase in temperature. **(5 points)**



2. A semi-infinite liquid with constant density (ρ) and viscosity (μ) is bounded below by a horizontal surface (the *xz*-plane). Initially, the liquid and the surface are stationary. Then at time $t = 0$, the solid surface begins to move in the positive *x*-direction with a constant velocity v_0 as shown in the following figure.



The equation of motion for the *x*-component of the velocity is

$$\frac{\partial v_x}{\partial t} = \frac{\mu}{\rho}\frac{\partial^2 v_x}{\partial y^2}$$

i) Derive the equation of motion for the *x*-component of the velocity using a shell balance approach. **(10 points)**

ii) Non-dimensionalize the variable *y*. **(5 points)**

iii) Non-dimensionalize the partial differential equations. **(10 points)**

iv) Write down the IC and BCs for the dimensionless differential equation. **(5 points)**

v) Solve the partial differential equation. **(10 points)**

3. A double-pipe heat exchanger is used, where cold water enters the inner pipe at an inlet temperature of 30°C and a flow velocity of 2 m/s. Hot water enters the outer pipe at an inlet temperature of 70°C. The fluids flow in a countercurrent configuration. The inner pipe diameter is 0.05 m, and the outer pipe diameter is 0.1 m. The inner pipe wall thickness of 1 mm and pipe material thermal conductivity of 50 $\frac{W}{m\,K}$. The physical properties of cold and hot water are the same: density ρ = 1000 $\frac{kg}{m^3}$ dynamic viscosity μ=0.001 $Pa\ s$, specific heat capacity c_p = 4.2 $\frac{kJ}{kg\,K}$ and thermal conductivity k = 0.6 $\frac{W}{mK}$. If the outlet temperature of the cold water is 40°C and the flow rates of cold and hot water are identical, calculate the required length of the double-pipe heat exchanger. **(25 points)**

Hint: $Nu = 0.023Re^{0.8}Pr^{n}$

where n = 0.4 (hot side) or n=0.3 (cold side)

Validity: $0.6 \leq Pr \leq 160$; $Re > 10000$; $\frac{L}{D} > 10$

4. In a chemical pipeline, corrosion occurs primarily due to the reaction between water and organic chlorides, producing ferric chloride ($FeCl_3$). When hydrochloric acid (HCl) is present, the corrosion rate is mainly controlled by the mass transfer rate of water to the pipe wall. Water (H_2O) is the limiting reactant, and corrosion occurs only when water reaches the pipe wall. The reaction at the pipe wall is extremely fast, and the water concentration at the wall (C_w) can be assumed to be zero. The primary reaction can be simplified as:

$$2Fe + 6H_2O + 3Cl_2 \rightarrow 2FeCl_3 + 6H_2$$

The known parameters are: Water concentration in the bulk(C_∞): 10 ppm(mass); Water diffusivity: D_{AB}=1.5×10^{-9} m^2/s; Flow velocity: u = 0.2 m/s; Pipe diameter: D = 0.05 m; Fluid density: ρ =1000 kg/m^3; Fluid viscosity: $\mu = 1.0\times10^{-3}$ kg/m-s; Molar mass of Fe: 55.845 g/mol; Molar mass of H_2O: 18 g/mol.

i) Calculate mass transfer coefficient, k_c when $f = 0.22$. **(10 points)**

ii) Calculate the corrosion rate of the pipe (Fe loss). **(15 points)**

Hint:

Coulburn-Chilton J-factor analogy:

$$J_M = \frac{f}{2} = J_H = \frac{Nu}{RePr^{\frac{1}{3}}} = J_D = \frac{Sh}{ReSc^{\frac{1}{3}}}$$

Mass transfer:

$$J = k_c \cdot A \cdot \Delta C$$

Where:

J: mass transfer rate

A: the pipe cross area,

ΔC: concentration driving force ($C_\infty - C_w$),

Kc: mass transfer coefficient