國立雲林科技大學
98 學年度碩士班入學招生考試試題

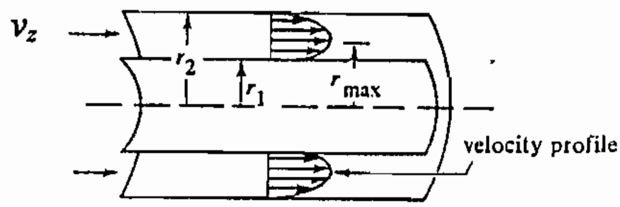
系所：化材系
科目：單元操作與輸送現象

1. If the equation of motion in cylindrical coordinates for z component is given by

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

Derive the equation for a steady-state laminar flow inside the annulus between two concentric horizontal pipes, as shown in Fig. 1.

Fig. 1



(a) Write the reduced differential equation by Eq. (1). (5%)

(b) Write two boundary conditions. (5%)

(c) Determine the velocity v_z at $r=2r_1$. (10%)

2. Consider the case of a laminar boundary layer over a flat surface. The von Karman momentum integral expression is shown by

$$\frac{\tau_0}{\rho}=\left(\frac{d}{dx}v_\infty\right)\int_0^\delta(v_\infty-v_x)dy+\frac{d}{dx}\int_0^\delta v_x(v_\infty-v_x)dy \quad (2)$$

(a) If the free-stream velocity v_∞ is constant, write the simplified equation by Eq. (2). (5%)

(b) If four boundary conditions are

(1) $v_x=0$, at y=0; (2) $v_x=v_\infty$, at y=δ; (3) $\frac{\partial v_x}{\partial y}=0$, at y=δ; (4) $\frac{\partial^2 v_x}{\partial y^2}=0$, at y=0

Derive the form of velocity profile while $v_x=a+by+cy^2+dy^3$. (5%)

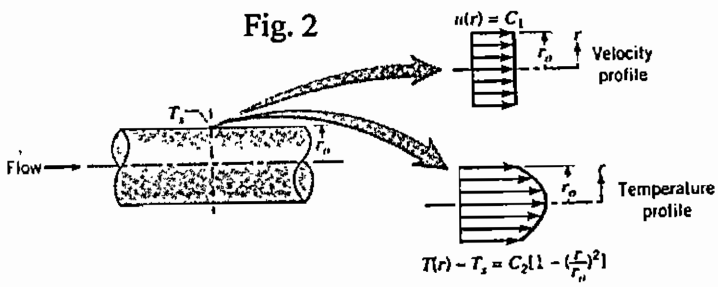
(c) If a differential equation in the thickness of the boundary layer δ results $\delta d\delta = \frac{140}{13}\frac{\nu dx}{v_\infty}$, find the local skin-friction coefficient C_{fx}. (5%) (Hint: $C_{fx} \equiv \frac{\tau_0}{(1/2)\rho v_\infty^2}$)

3. For an internal flow through a circular tube as shown in Fig. 2, the velocity and temperature profiles are assumed by

$$u(r) = C_1 \text{ and } T(r) = T_s + C_2\left[1-\left(\frac{r}{r_o}\right)^2\right] \quad (3)$$

and the mean temperature is $T_m = \frac{2}{u_m r_o^2}\int_0^{r_o} uTr dr$, where u_m is the mean velocity.

Fig. 2



(a) Find the surface heat flux. (5%)

(b) Find the local convection heat transfer coefficient h. (5%)

(c) Find Nusselt number. (5%)

國立雲林科技大學
98學年度碩士班入學招生考試試題

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4. A cylindrical rod is rotating about its own axis at an angular velocity Ω in a very large pool of liquid of constant density and viscosity. The rod axis is vertical. Find the steady state shape of the free surface. (10%)

The following equations of motion may be used.

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

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

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

5. A mixture of reactant A and spherical particles ($r = R_0$) coated with catalytic material is placed inside a spherical reactor. The reactor's walls are heated so that the heterogeneous reaction A → 2B takes place at the catalyst surface. The catalyst particle is surrounded by a gas film of thickness δ. The spherical shape of the particle cannot be neglected.

Using the equation of continuity for A, set up (but do not solve) the differential equation giving x_A as a function of r. List the assumptions and the boundary conditions for the case where

(a) the reaction proceeds instantaneously and irreversibly. (10%)

(b) what change is there if the reaction proceeds slowly at the surface with a rate constant for the reaction of k, where k is $0 < k << 1$? (5%)

6. A wastewater stream is introduced to the top of a mass-transfer tower where it flows countercurrent to an air stream. At one point in the tower, the wastewater stream contains 1×10^{-3} gmol A/m^3 and the air is essentially free of any A. At the operating conditions within the tower, the film mass-transfer coefficients are $k_L = 5\times10^{-4}$ kgmol/(m^2•s•kgmol/m^3) and $k_G = 0.01$kgmol/(m^2•s•atm). At the specified plane, $C_{A,L}$= 1.0×10^{-6} kgmolA/m^3) and $P_{A,G}$ =0. The concentrations are in the Henry's law region where $P_{A,i} = HC_{A,i}$ with H = 10 atm/(kgmole/m^3). Determine (a) the overall mass flux of A. (5%) (b) the overall mass-transfer coefficients K_L and K_G. (10%)

7. Define the following terms. (10%)

(a) Chilton-Colburn analogy for heat transfer

(b) j-factor for mass transfer

(c) Sherwood No. (d) Newtonian fluid (e) Biot No.

國立雲林科技大學
98 學年度碩士班入學招生考試試題
系所：化材系
科目：化工熱力學

1. (20%)

Derive the following Maxwell relations for open systems.

(a) $(\partial S/\partial V)_{T,N} = (\partial P/\partial T)_{V,N}$ (10 %)

(b) $(\partial S/\partial N)_{T,V} = -(\partial \underline{G}/\partial T)_{V,N}$ (10 %)

Starting from $dA = -PdV - SdT + \underline{G}dN$

2. (20%)

One mole of a gas at a temperature of 25°C and a pressure of 1 bar (the initial state) is to be heated and compressed in a frictionless piston and cylinder to 300°C and 10 bar (the final state). Compute the heat and work required along each of the following paths.

(a) Isothermal (constant temperature) compression to 10 bar, and then isobaric (constant pressure) heating to 300°C. (10 %)

(b) Isobaric heating to 300°C followed by isothermal compression to 10 bar. (10 %)

For simplicity, the gas is assumed to be ideal with $C_p^* = 38$ J/(mol K) and R = 8.314 J/(mol K).

3. (10%)

If the heat capacity of an ideal gas is given by $C_v^* = (a-R) + bT + cT^2 + dT^3 + e/T^2$

Show that $\underline{S}(T_2, \underline{V}_2) - \underline{S}(T_1, \underline{V}_1) =$

$(a-R)\ln(T_2/T_1) + b(T_2-T_1) + (c/2)(T_2^2-T_1^2) + (d/3)(T_2^3-T_1^3) - (e/2)(T_2^{-2}-T_1^{-2}) + R\ln(\underline{V}_2/\underline{V}_1)$

國立雲林科技大學
98 學年度碩士班入學招生考試試題

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4. (20%)

Ethanol (EOH) and n-hexane (H) are put into an evacuated, isothermal container. It is observed that two liquid phases and a vapor phase are in equilibrium at 75°C. One of the liquid phases contains 9.02 mole% n-hexane. Activity coefficients (γ_i) for n-hexane-ethanol liquid mixtures can be represented by the following equation ($i \neq j$). Assuming an ideal vapor phase, compute

(a) fractional mole compositions of two liquid phases at equilibrium ? (8%)

(b) equilibrium pressure (bar) of the system ? (6%)

(c) fractional mole composition of the vapor phase ? (6%)

$$RT \ln \gamma_i = 8.163 x_j^2 \frac{\text{kJ}}{\text{mol}}$$

Data Vapor pressure equations (T in K, P in bar)

$$\ln P_{\text{H}}^{\text{vap}} = \frac{-3570.58}{T} + 10.4575$$

$$\ln P_{\text{EOH}}^{\text{vap}} = \frac{-4728.98}{T} + 13.4643$$

5. (15%)

A process is developed to produce high-purity titanium. As part of the proposed process, titanium will be kept in a quartz (silicon dioxide) crucible at 1273 K. A chemical engineer working on the process is concerned that the titanium could reduce the silicon dioxide, producing titanium dioxide and element silicon, which would lower the purity of the titanium. Is this concern justified ?

Data At 1273 K

$$Ti(s) + O_2(g, 1\ \text{bar}) = TiO_2(s) \qquad \Delta \underline{G}_{\text{rxn}}^{\circ} = -674\ \text{kJ/mol}$$

$$Si(s) + O_2(g, 1\ \text{bar}) = SiO_2(s) \qquad \Delta \underline{G}_{\text{rxn}}^{\circ} = -644\ \text{kJ/mol}$$

6. (15%)

A graduate student is assigned to conduct a fugacity study for oxygen and nitrogen gases. He reports that fugacity coefficient is 1.025 for pure oxygen and is 1.36 for pure nitrogen at 290 K and 800 bar. Determine the fugacity of oxygen and of nitrogen in air (an ideal solution assumed) at 290 K and 800 bar.

國立雲林科技大學
98 學年度碩士班入學招生考試試題

系所：化材系
科目：化工動力學

本試題兩頁共 6 題，合計 100 分。請依題號作答，並將演算過程及答案寫在答案卷上，違者不予計分。

1. (20%) The irreversible reaction A + B → AB has been studied kinetically, and the rate of formation of product has been found to be well correlated by the following rate equation:

$$\gamma_{AB} = \frac{k_0 C_A^{\,2} C_B}{1 + k' C_B}$$

Please derive the reaction mechanism by this rate expression and start with two-step reversible model. The chemistry of the reaction suggests that the intermediate consists of an association of reactant molecules and that a chain reaction does not occur.

2. (20%) For the elementary reactions in series

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

where $2k_1 = k_2$, at t = 0, $C_A = C_{A0}$, $C_{B0} = C_{C0} = 0$

Please find the maximum concentration of B and when it is reached.

3. (10%) Please explain the following descriptions:

(a) Reactions with high activation energy are very temperature sensitive; reactions with low activation energy are relatively temperature insensitive.

(b) Reactions are much more temperature sensitive at a low temperature than at a high temperature.

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98學年度碩士班入學招生考試試題
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[$e = 2.718$, $e^2 = 7.39$, and $\ln(10) = 2.3$]

4. (20%) The elementary gas-phase reaction $A \rightarrow B + 2C$ is carried out isothermally in a well-mixed flow reactor with no pressure drop. The specific reaction rate at 27 °C is 10^{-4} min^{-1} and the activation energy is 99.72 kJ/mol. Pure A enters the reactor at 10 atm and 127 °C and molar flow rate of 2.5 mol/min. Calculate the reactor volume to achieve 90% conversion.(R = gas constant = 0.082 atm-dm^3/mol-K = 8.31·J/mol-K)

5. (15%) A slow, first-order liquid reaction is carried out in a fixed-volume, well-mixed flow reactor under isothermal conditions. Let τ and T_s be the space time and the time necessary to reach 99% of the steady-state concentration, respectively. Please derive the following relation: $T_s = 4.6\,\tau$.

6. (15%) A reaction $A \rightarrow B$ was carried out in a plug-flow reactor and the following data were recorded:

Conversion, X	0	0.2	0.4	0.5	0.6	0.8	0.9
$-r_A$ (mol/dm^3-min)	10	16.67	50	50	50	12.5	9.09

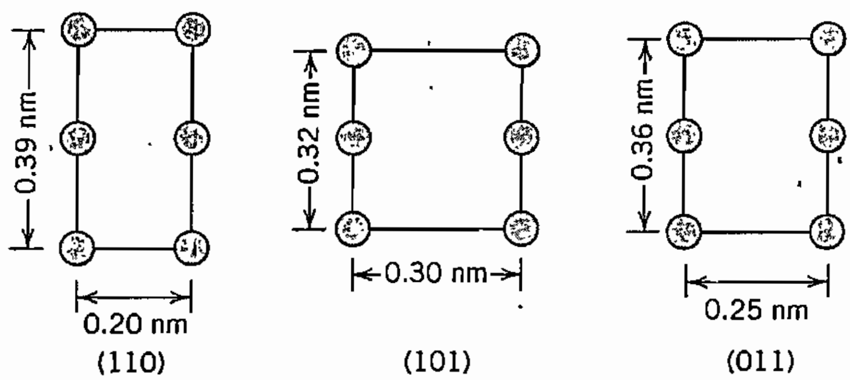
The entering molar flow rate of A was 300 mol/min. What is the plug-flow reactor volume necessary to achieve 40% conversion?

國立雲林科技大學
98學年度碩士班入學招生考試試題

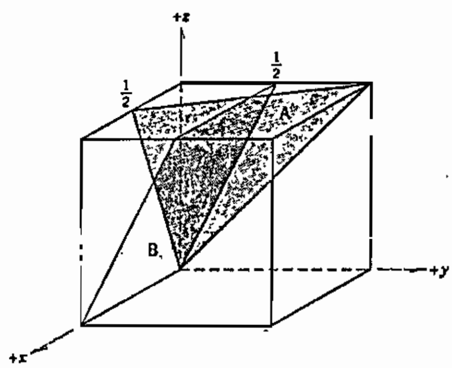
系所：化材系
科目：材料科學導論

1. Write out how many atoms in a unit cell, coordination number, and atomic packing factor for the following crystal structure: (9%)
(a) BCC, (b)FCC, (c)HCP.

2. Below are shown three different crystallographic planes for a unit cell of some hypothetical metal. The circles represent atoms: (15%)
(a) To what crystal system does the unit cell belong (write out the axial lengths and angles)?
(b) What would this crystal structure be called?
(c) If the density of this metal is 18.91 g/cm^3, determine its atomic weight.



3. Determine the Miller indices for the planes shown in the following unit cell: (8%)



4. In general, dislocations include three types, (a) What are they? (b) What are the relative orientations of Burgers vector and the three types? (6%)
5. If a Ca^{2+} ion substitutes for a K^+ ion in the potassium chloride (KCl) crystal,
   (a) What point defects are possible to form in order to maintain charge neutrality (3%)
   (b) How many of these defects exist for every Ca^+ ion? (3%)
   (c) What are the meanings of "Frenkel defects" and "Schottky defects"? (6%)

6. Explain the concept of the viscoelastic deformation, stress relaxation, and viscoelastic creep behaviors of the polymeric materials. (10 %)

7. Sketch schematic the relaxation modulus-temperature plots for the almost totally crystalline isotactic polystyrene, the lightly crosslinked atactic polystyrene, and the amorphous polystyrene, respectively. (10 %)

8. (10 %)

The density and associated percent crystallinity for two polyethylene materials are as follows:

ρ (g/cm^3)	Crystallinity
0.965	76.8
0.925	46.4

(a) Compute the densities of totally crystalline and totally amorphous polyethylene.

(b) Determine the percent crystallinity of a specimen having a density of 0.950 g/cm^3.

9. (20 %)

From the tensile stress-strain behavior for the brass specimen shown in Figure 1, determine the following:

(a) The modulus of elasticity.

(b) The yield strength at a strain offset of 0.002.

(c) The maximum load that can be sustained by a cylindrical specimen having an original diameter of 12.8 mm (0.505 in.).

(d) The change in length of a specimen originally 250 nm (10 in.) long that is subjected to a tensile stress of 345 MPa (50,000 psi).

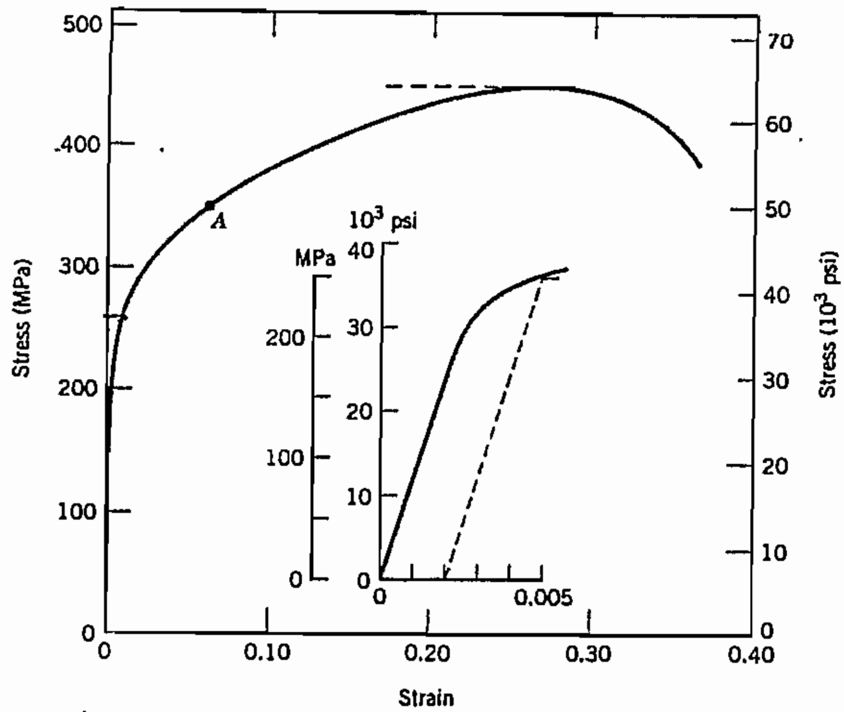


Fig.1. The stress-strain behavior for the brass specimen

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系所：化材系
科目：物理化學

1. The equilibrium constant of a reaction is found to fit the expression $\ln K = A + B/T + C/T^2$ between 400 K and 600 K with $A = -1.76$, $B = -1368$ K, and $C = 1.1 \times 10^5$ K^2. Calculate the standard reaction enthalpy and standard reaction entropy at 500 K. (20%)

2. Use the standard emfs of the couples Au^+/Au (1.69 V), Au^{3+}/Au (1.4 V) and Fe^{3+}/Fe^{2+} (0.77 V) to calculate the standard emf and equilibrium constant of the following reaction at 298 K.
$2Fe^{2+}(aq) + Au^{3+}(aq) <=> 2 Fe^{3+}(aq) + Au^+(aq)$ (15%)

3. The gas-phase decomposition of acetic acid at 1189 K proceeds by way of two parallel and elementary reactions:
(1) $CH_3COOH \xrightarrow{k_1} CH_4 + CO_2$
(2) $CH_3COOH \xrightarrow{k_2} CH_2CO + H_2O$
If the initial concentration of CH_3COOH is $[A]_0$, and no CH_4, CO_2, CH_2CO, and H_2O are present initially. Find an expression for the concentration of CH_2CO as a function of the time. (15%)

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98學年度碩士班入學招生考試試題

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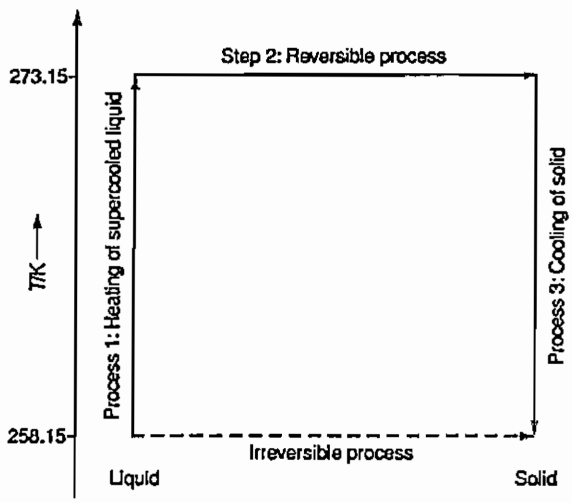
4. Find ΔH and q if 2.000 mol of supercooled liquid water at -15.00℃ freezes irreversibly at a constant pressure of 1.000 atm to ice at -15.00℃. Assume the molar heat capacity of liquid water to be constant and equal to 76.1 $JK^{-1}mol^{-1}$, and that of ice to be constant and equal to 37.15 $JK^{-1}mol^{-1}$. The specific enthalpy change of fusion of water is 333.5 Jg^{-1}. Please calculate along the reversible path as shown below. (15%)



5. Sketch rough graphs representing the changes in thermodynamic properties including V(volume), H(enthalpy), S(entropy), C_p(heat capacity), with temperature(T) accompanying (a) first-order and (b) second-order phase transitions. 【15%，(a) 7%，(b) 8%】

6. (i) Calculate the Gibbs energy change of mixing, the entropy change of mixing, the enthalpy change of mixing, and the volume change of mixing for an ideal solution of 1.200 mol of benzene and 1.300 mol of toluene at 20.0 ℃. (10%)

(ii) Find the partial vapor pressure of each component, the total vapor pressure, and the composition of the vapor at equilibrium with the above solution. The vapor pressure of pure benzene at 20.0 ℃ is equal to 74.9 torr, and that of pure toluene at this temperature is 21.6 torr. (10%)