經濟部所屬台灣中油股份有限公司 102 年新進博士級人員甄試試題

類　　別：化學工程(A)

專業科目：化工原理(含反應工程與輸送現象)

注意事項	1.本試題共 5 頁（A4 紙 5 張）。 2.本試題共 14 題，合計 100 分，各題配分標示於題後。須用藍、黑色鋼筆或原子筆**在答案卷指定範圍內標題號(不必抄題)**依題目順序作答，於本試題或其他紙張作答者不予計分。 3.考試結束前離場者，試題須隨答案卷繳回，俟該節考試結束後，始得索取。 4.考試時間：150 分鐘

一、Several important parameters usually appear in a flow system. These parameters include:

1. average fluid speed V
2. a characteristic length L
3. fluid viscosity μ
4. surface tension σ
5. gravitational factor g
6. fluid density ρ

What are the definitions of Reynolds number and Froude number? Can you also explain the physical meaning of these two numbers?（4 分）

二、As shown in Figure 1, we consider a solid of volume V, density ρ, heat capacity C_p and surface area A. We assume that the body has a spatially uniform but time-dependent temperature T(t) and losses heat to the surroundings by convection from its surface. Assuming the time rate of change of the thermal energy within the solid body is due to the convective heat exchange with the surroundings, and the rate of convection is a linear function of the temperature difference between the surface and the surroundings, set up the heat balance equation and solve for temperature variation as a function of time. The initial temperature of the body is T_o.（8 分）

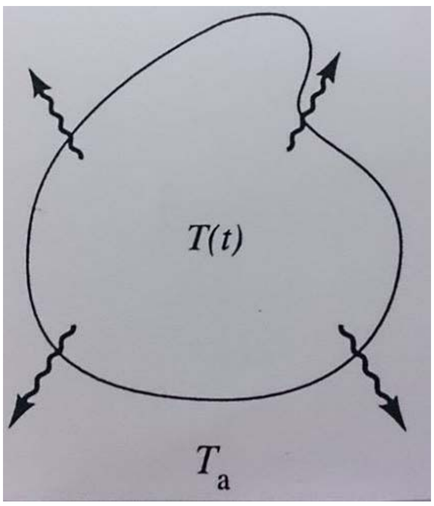


Figure 1　Heat loss to surroundings

三、Consider a liquid drop contains a supersaturated solution with concentration $C_{A,sat}$ as shown in

Figure 2. The solute is volatile and it has a vapor pressure $P_{A,sat}$. The vapor concentration of the solute on the surface of the liquid drop is C_R. The saturated drop is surrounded by a large body of stagnant gas. The radius of the liquid drop is R. Assume that the solution remains supersaturated throughout the process, prove that the Sherwood number (S_h) of this system is equal to 2. (6 分)

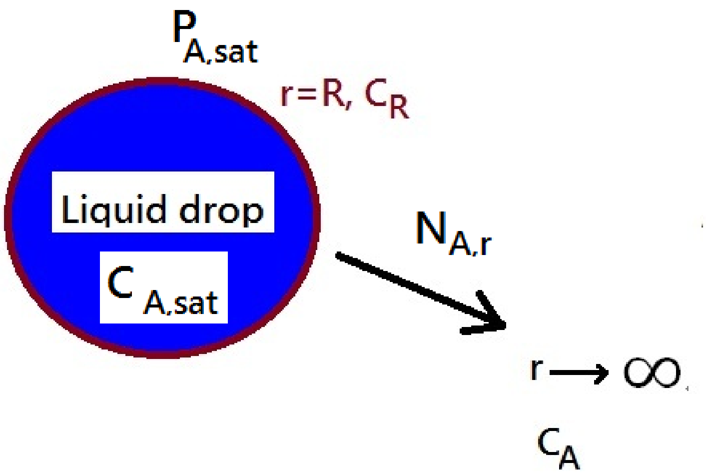


Figure 2　Solute evaporation system

四、Estimate the maximum diameter of a spherical particle that could be carried away in a fluidized bed reactor under the following condition:

Gas velocity at the top of the reactor = 10 cm/s (vertically upward)

Gas viscosity = 0.026 cp;　1cp=0.01 poise= 0.001 Pa·s=0.001 kg/m-sec

Gas density = 0.72 kg/m^3

Density of the spherical particle= 2.33 g/cm^3 =2330 kg/m^3

The drag force of a spherical solid sphere is $F_{\text{drag}} = 6\pi\mu R u_t$.

Where

μ : Viscosity of gas

R : Radius of particle

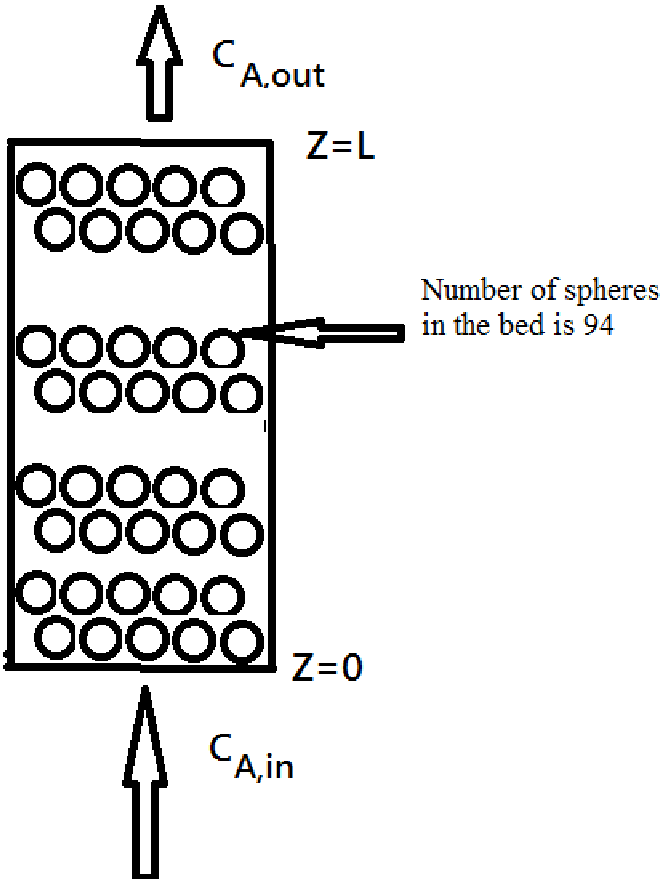
u_t : Terminal velocity of particle

Express the result in microns. (6 分)

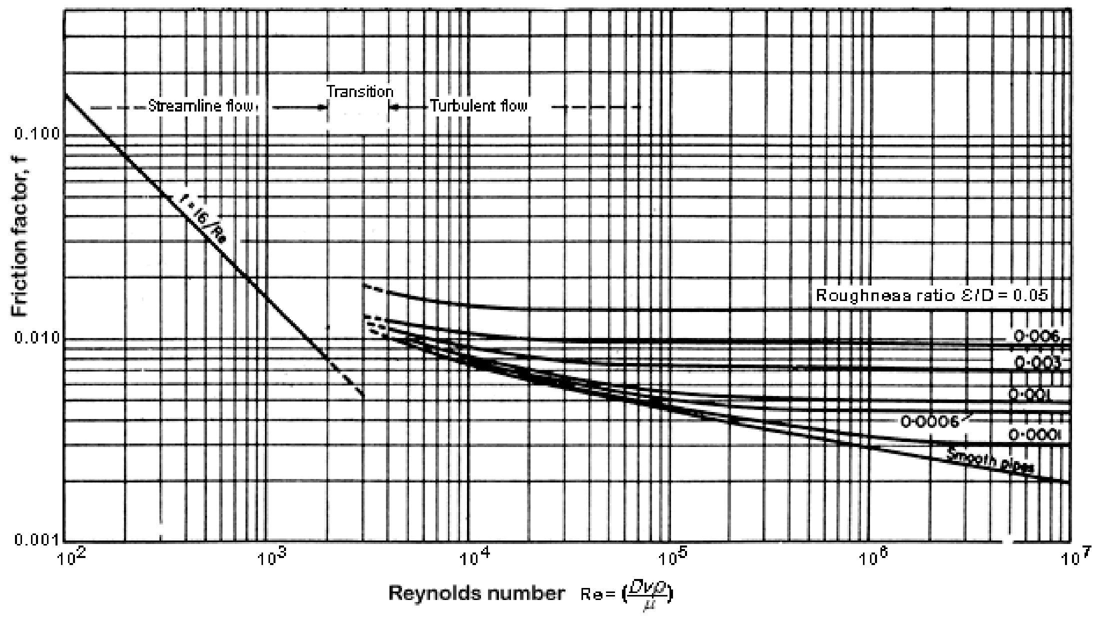
五、Please state the assumptions for deriving the Navier-Stokes equation. (2 分)

$$\rho\frac{D\mathbf{v}}{Dt} = -\nabla p + \mu\nabla^2\mathbf{v} + \rho\mathbf{g}.$$

六、 Pure water at 26.1 ^{o}C ($C_{A,in}$) flows at the rate of 5.514x10^{-7}m^3/s (F) through a packed bed of benzoic acid spheres having a diameter of 6.375 mm (D_p). The number of spheres in the bed is 94 and the void fraction is 0.436. The diameter of the packed-bed column is 0.0667 m (D_t). The solubility of benzoic acid in water is 2.948x10^{-2} kg-mol/m^3 ($C_{A,S}$). The outlet concentration of benzoic acid in the water from the packed bed is 2.842x10^{-3} kg-mol/m^3 ($C_{A,out}$). The diffusivity of benzoic acid in water is 1.254x10^{-9} m^2/s. The viscosity of water at 26.1 ^{o}C is 0.8682 cp. Evaluate the mass transfer coefficient k_m of benzoic acid in water. Assume that the density of the fluid is constant. (8 分)



七、雷諾(Osborne Reynolds)進行了牛頓流體(Newtonian fluids)流經水平之直圓管的實驗，某工程師重覆雷諾實驗，發現以下變數影響牛頓流體流經水平直圓管的壓力降(pressure drop，ΔP (kg/m-s^2))：管內徑(inner diameter，D(m))、管長(pile length，L(m))、流體平均流速(fluid mean velocity，V(m/s))、流體黏度(fluid viscosity，μ(kg/m-s))、流體密度(fluid density，ρ(kg/m^3))、管內平均粗糙度(roughness，ε(m))，



請協助某工程師估計原油(ρ=860 kg/m^3；μ=0.0009 kg/m-s)以 0.316 公升/秒流量流過總長 10 米之 1 吋鐵管(ε=0.046 mm)的壓力降。(6 分)

八、一實心圓球(直徑D(m)、熱傳導係數(thermal conductivity，k_S(J/m-K))、比熱(heat capacity，C_{pS}(J/kg-K))、密度ρ_S(kg/m^3)內部以體積產熱率(Q(W/m^3))產熱，置於一無限大牛頓流體(熱傳導係數k(J/m-K)、黏度μ(kg/m-s)、比熱C_p(J/kg-K)、密度ρ(kg/m^3)、溫度T_L (K))中，實心圓球為銅球(D=1 cm、k=401 W/m-K、C_{pS}=378 J/kg-K、ρ_S=8960 kg/m^3、Q=1000,000W/m^3)，置於流動之空氣(μ=0.00002 kg/m-s、ρ=1.2 kg/m^3、T_L=300 K)流中，熱傳係數(heat transfer coefficient，h=50 W/m^2-K)，

(1) 請利用殼層能量平衡導出實心圓球穩態溫度分佈式。(7 分)，

(2) 計算實心圓球穩態中心溫度為何?(3 分)

九、The hydrolysis of A is catalyzed by one of the reaction products, C

$$A + H_2O \rightarrow C + P$$

If the rate expression is $-\frac{dA}{dt} = kAC$ and the initial concentrations of A and C are A_0 and C_0, respectively, verify the following results:

(a) Conversion $x = \frac{1-\exp(-Mkt)}{1+(A_0/C_0)\exp(-Mkt)}$ where $M = A_0 + C_0$ (5 分)

(b) Maximum reaction rate in the above system occurs when $A = M/2$ (4 分)

十、When properly operated, which contacting pattern on the left or the right can give a higher concentration of any intermediate for the four cases exhibited as shown in Figure 3(a), (b), (c), and (d) respectively? The reaction order shall be positive. (8 分)

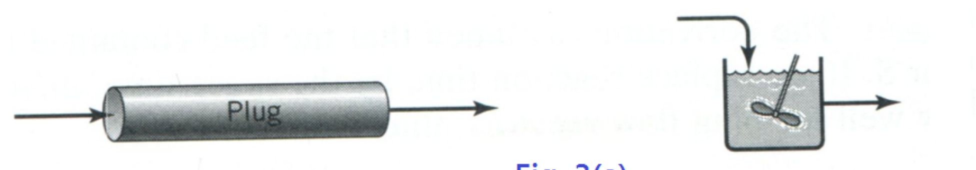


Fig. 3(a)

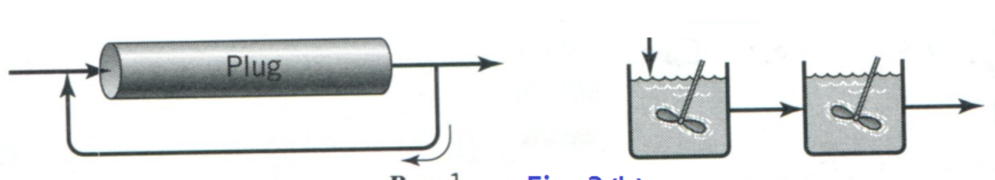
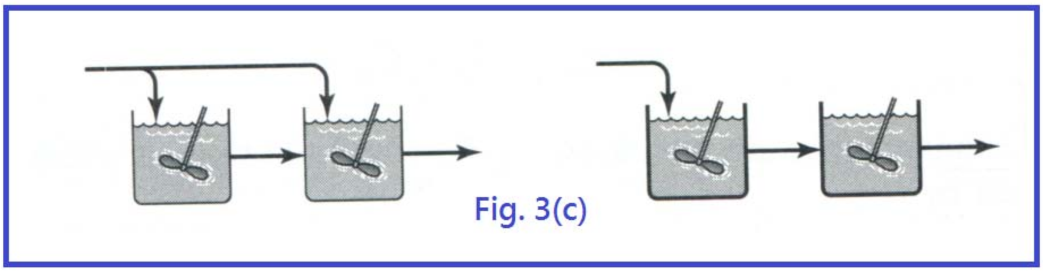


Fig. 3(b)



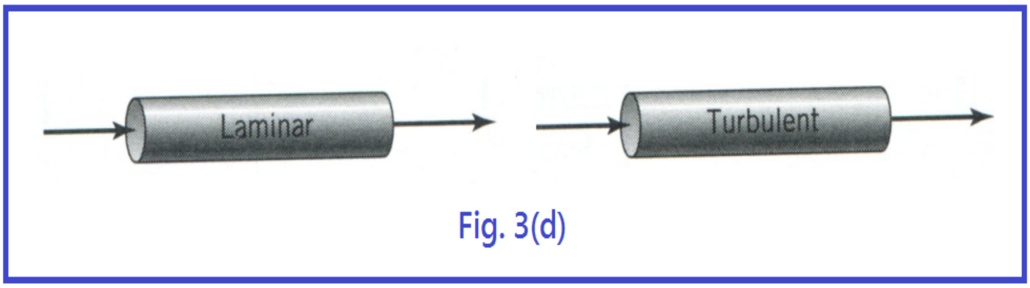


Figure 3 (a), (b), (c), (d)

十一、The following equation is reported to describe the adiabatic operation of both CSTR and PFR, $X_A = C_P(T_{out} - T_{in})/(-\Delta H_{r,\,Tout})$ = (heat needed to raise feed to T_{out})/(heat released by reaction at T_{out}), where A represents the limiting reactant. Please try to derive the equation to verify its adequacy. Based on the equation, plot the "operating line" of X_A vs T considering the effect of reaction enthalpy being endothermic and exothermic. （8 分）

Assume $\dot{m}_{unreacted} \cong \dot{m}_{in}(1 - X_A)$ and $\dot{m}_{reacted} \cong \dot{m}_{in}X_A$

十二、A stirred tank reactor is usually assumed as ideal perfect mixing when performing reactor design. However, dead space and bypass can occur due to uneven stirring caused by improper mixing parameters. Consequently, a non-ideal stirred tank reactor will have a different residence time distribution (RTD) from that of an ideal CSTR. Please model the RTD of a non-ideal stirred tank reactor with dead space and bypass, expressed in terms of α, fraction of active reactor volume, and β, fraction of bypass flow. Explain how you may be able to resolve α and β from a tracer experiment. （8 分）

十三、A reaction, $A + B_2 \rightarrow C$, has the following mechanism,

$A + S = A \cdot S$

$B_2 + 2S = 2B \cdot S$

$A \cdot S + B \cdot S \rightarrow C + 2S$

If a surface reaction is a rate limiting step, derive the rate law of the reaction. （9 分）

十四、Milk is pasteurized if it is heated to 63°C for 30 minutes, but if it is heated to 74°C it only needs 15 seconds for the same results. Find the activation energy of this pasteurization process. （8 分）