國立臺北科技大學 103 學年度碩士班招生考試

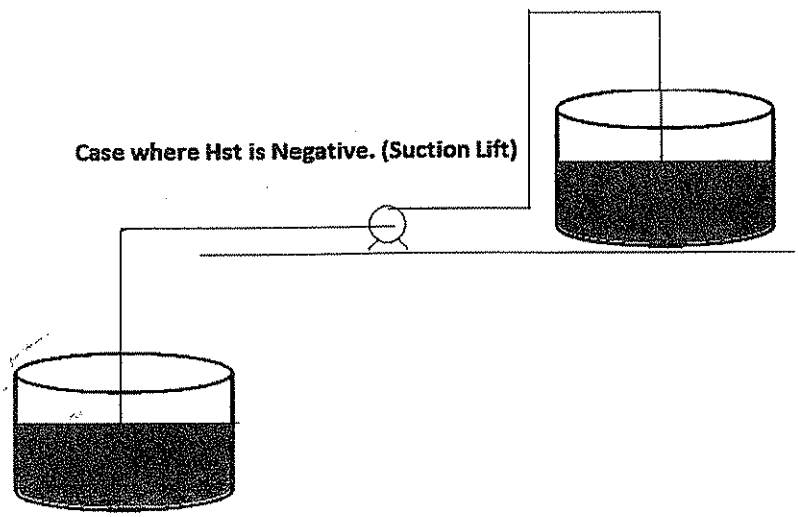
系所組別：3510 化學工程與生物科技系化學工程碩士班甲組

第一節　單元操作與輸送現象　試題

注意事項：

1. 本試題共五題，配分共 100 分。
2. 請標明大題、子題編號作答，不必抄題。
3. 全部答案均須在答案卷之答案欄內作答，否則不予計分。

1. Liquid butane in the left tank A at 90°F with surface pressure of p_A = 50 psia is pumped at a rate of 100 gal/min through the pipeline system as shown below to the right tank B with surface pressure of p_B = 50 psia. The discharge level in tank B is 12 ft above the centerline of the pump, and the pump suction is 8.0 ft above the level in tank A. The friction head loss in the suction line is 15 ft, and that in the discharge line is 18 ft. The density of butane at 90°F and 60 psia is 36.2 lb/ft^3, and its vapor pressure is 44 psia. Calculate the (a) total suction head expressed as H_S(ft) of fluid being pumped, (b) total discharge head H_D and (c) the total head H developed by the pump. (d) If the pump manufacturer specifies a required NPSHR of 10 ft at 100 gpm, calculate the net positive suction head (NPSHA) available for the pump and determine whether it is going to have a cavitation problem or not? (e) If there is not enough NPSHA, how to increase NPSHA to a centrifugal pump?
(a~e 各配 4 分，共計 20 分)



2. In the 1-2 shell-and-tube heat exchanger sketched in Figure(C), is used to recover heat from an oil stream with a heat-transfer area of $A_o = 15\ m^2$ and overall heat-transfer coefficient of $U_o = 250\ W/m^2 \cdot K$. The oil enters the heat exchanger at 375 K as the tube-side fluid and flows at a rate of 0.5 kg/s. The water enters at 280 K as the shell-side fluid and flows at a rate of 0.556 kg/s. The fluid properties are given below: $C_{p,\,oil} = 2{,}090\ J/kg \cdot K$, $C_{p,\,water} = 4{,}177\ J/kg \cdot K$. (a) What will be the exit temperatures of the water and oil, respectively? (b) And what is the average rate of heat transfer between oil and water? (c) What is the correct log-mean-temperature-difference (LMTD), by comparing the 1-2 exchanger and a new 2-4 exchanger at the same inlet, outlet temperatures? and (d) what is the outside surface area A_o of tubes in the 2-4 exchanger required for the same heat-transfer rate as in the 1-2 exchanger? (a, b, c, d 各配 6, 5, 6, 3 分，共計 20 分)

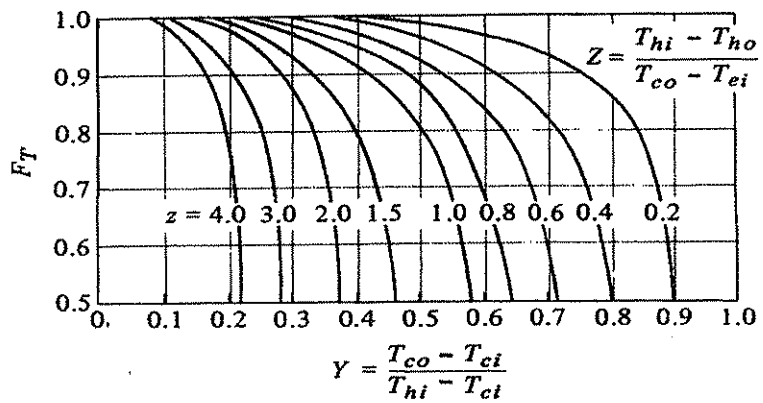


Fig. (A) Correction of log mean temperature difference for 1-2 exchanger. T_{hi}, T_{ci} denote the respective inlet temperatures of hot and cold fluids; T_{ho}, T_{co} denote the respective outlet temperatures of hot and cold fluids.

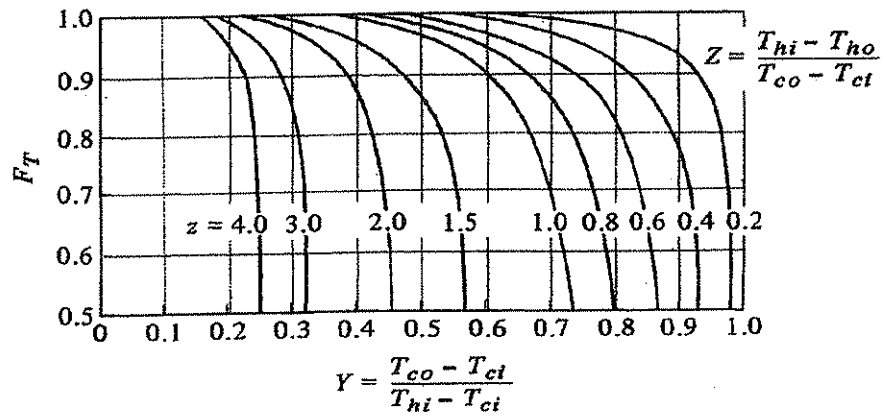


Fig. (B) 2-4 Correction of log mean temperature difference for 2-4 exchanger.

注意：背面尚有試題

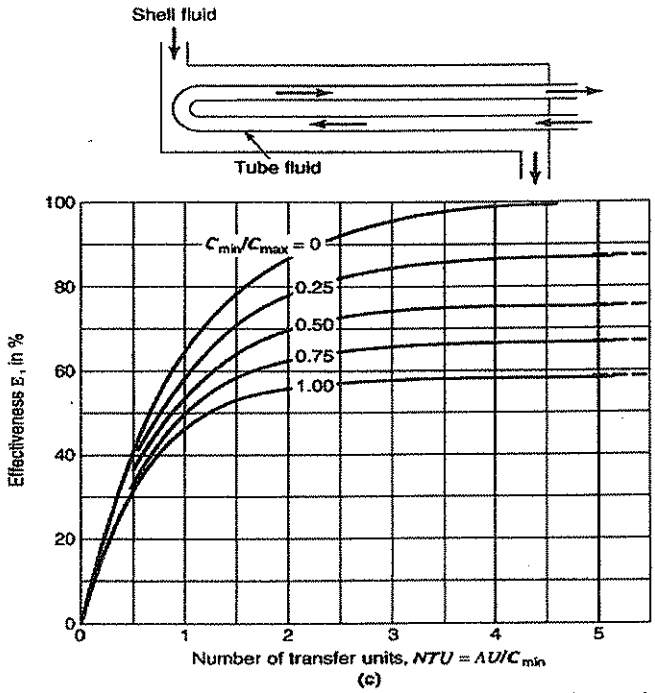
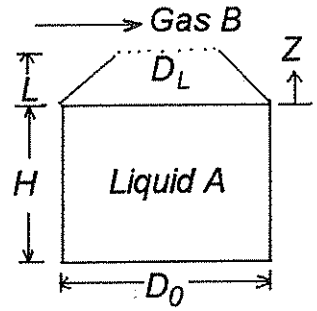


Fig. (C) Effectiveness of 1-2 exchanger versus number of transfer units N_H.

3. To decrease the evaporation loss of liquid (A) from open storage tank to air (B), it is to use a tapered top design, in which the top roof is becoming gradually narrower as shown below. If the taper angle in a circular cone-like geometry is small, mass transport is only in the z-direction. The cylindrical tank of height $L+H$ and diameter D_0 is partially filled with a pure liquid (A) up to a level of H. The apparatus is arranged in a way that the liquid-gas interface remains fixed in space at H as the evaporation takes place. Assuming the steady-state conditions at constant temperature and pressure, there is no chemical reaction between species A and B, and species B has a negligible solubility in liquid A. Component A vaporizes and diffuses into a gas mixture of A and B. (a) Develop a mathematical model to predict the combined molar diffusion flux of A through a stagnant gas-film above the surface of the liquid. (b) Calculate the average molar rate of ethanol loss from the storage tank under steady-state conditions at 1 atm and 25°C.



The given properties at 1 atm and 25°C and numerical values are the saturation vapor pressure of liquid ethanol $p_A^{sat} = 58.6$ mmHg, diffusion coefficient of ethanol in air $D_{AB} = 1.35\times10^{-5}$ m^2/s, $H = D_0 = 3.0$ m , $D_L = L = 1.0$ m, and molecular weight of ethanol $M_A = 46$. (a, b 各配 8, 12 分，共計 20 分)

4. Consider a flowing problem: an incompressible fluid is flowing horizontally inside a circular tube of inside diameter D and length L. The significant experimental variables are pressure drop Δp, average velocity $\overline{V}$, diameter D, length L, fluid density ρ, and fluid viscosity μ. (a) Determine the important dimensional groups into which the experimental variables can be combined by using dimensional analysis, and develop a mathematical expression including the Reynolds number. (b) Briefly compare the advantages and disadvantages of either Buckingham Pi method or Rayleigh method of dimensional analysis. (hint: Select ρ, D, and $\overline{V}$ as the core variables. Use the $[M]$, $[L]$, $[t]$ system of basic units, and the unit of Δp as $[M][t]^{-2}[L]^{-1}$.)
(a, b 各配 15, 5 分，共計 20 分)

5. 請簡要解釋下列單元操作名詞 (每小題5分，請依序作答，共計20分)

(1) 非牛頓流體之冪次定律 (Power law for non-Newtonian fluids)
(2) 氣體吸收之雙膜理論 (Two-film resistance theory for gas absorption)
(3) 精餾之分士克方程式 (Fenske equation for fractional distillation)
(4) 濕度圖之路易士關係式 (Lewis relation for psychrometric chart)