題號： 233 國立臺灣大學101學年度碩士班招生考試試題

科目：輸送現象及單元操作

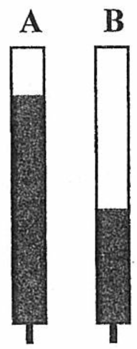
節次： 8



1. Explain the following phenomena:

(a) Flowing a liquid through a pipe results in a pressure drop between two ends of the pipe. A student found that at a fixed volumetric flow rate, a decrease in the viscosity of the liquid descended the pressure drop between the two ends of the pipe. However, when the liquid viscosity was further decreased, the pressure drop was found to increase. **(3 points)**

(b) Two tubes (A and B) with the same diameter are filled with a Newtonian fluid at a height ratio of 2 (A) to 1 (B).




(i) What is the ratio of flowrate ($v_A/v_B$) of the liquid from the bottom of the tubes by gravity? Why? **(3 points)**

(ii) The Newtonian liquid in the tubes is replaced by an unknown liquid. A student found that the ratio of the flowrate ($v_A/v_B$) is increased compared with Newtonian fluids. Which kind of fluid is the unknown liquid, pseudoplastic, dilatant or Bingham? Why? **(4 points)**

2. Bronchi（支氣管）that are located two generations down the respiratory tree from the trachea（氣管）have a mean diameter (d) of 9.4 mm and a length (L) of 30.3 mm. Air flow in the lung during inspiration is 1 liter/second (0.25 liter/second per bronchus).

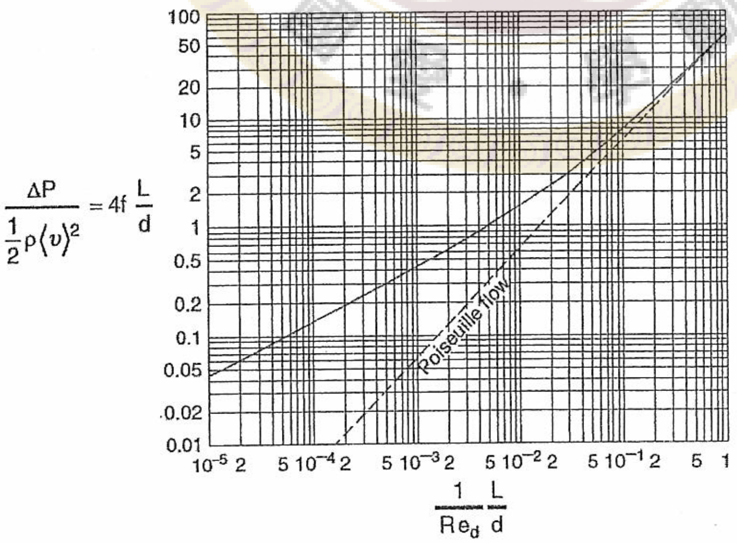
(a) Without considering the entry effect, estimate the pressure difference **(cm $H_2O$)** across these bronchi. **(8 points)**

(b) When the entry effect is considered, the pressure drop is deviated from Hagen-Poiseuille equation. Please use the following diagram to estimate:

(i) Fanning friction factor (f) **(4 points)**

(ii) The pressure difference (ΔP; **cm $H_2O$**) across these bronchi. **(8 points)**

ρ: density of air = $1.1 \times 10^{-3}$ g/cm$^3$; <v>: average velocity; $Re_d$: Reynolds number




3. A spherical water droplet is suspended from a fine thread in still, dry air. If the characteristic length is the diameter of the droplet, please determine the magnitude of Sherwood number for mass transfer from the surface of the water droplet into the surroundings. **(6 points)**

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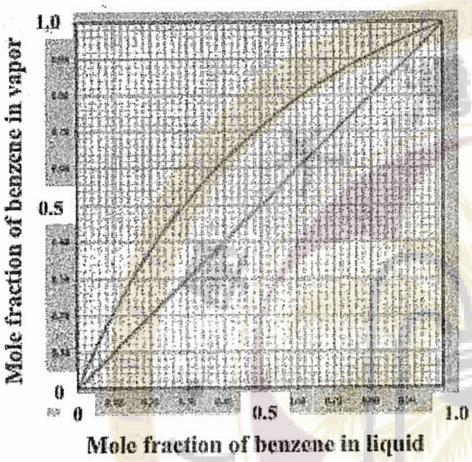
4. Distillation is a common method for separating mixtures based on differences in volatilities of components in a boiling liquid mixture.

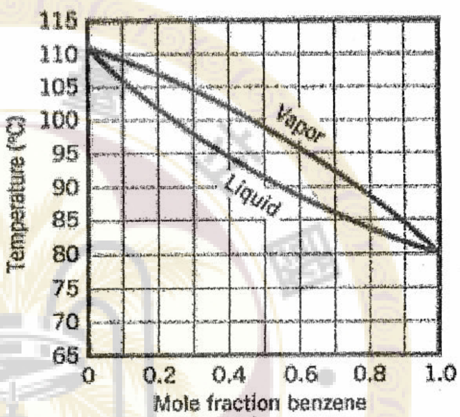
(a) Explain the following terms: differential distillation, equilibrium or flash distillation, rectification **(6 points)**

(b) A mixture that is 70 mole% benzene and 30 mole% toluene is to be distilled in a flash distillation column. When the feed is 30% vaporized, use the equilibrium data given below to determine

(i) The composition of the liquid and vapor leaving the column. **(5 points)**

(ii) The temperature of the exit liquid stream **(3 points)** **(if you don't know how to calculate the composition, use 40% benzene in liquid to determine the temperature)**




(a) Txy diagram

(c) What is an azeotrope? What are azeotropic distillation and extraction distillation? What is membrane distillation? **(6 points)**

5. A counterflow heat exchanger is employed to transfer heat from hot oil to water. The flow rate of the oil is 0.25 kg/s and the oil enters at $T_{h,i}$ = 220°C. The water flow rate is 0.3 kg/s and it enters at $T_{c,i}$ = 20°C. The desired water outlet temperature is $T_{c,o}$ = 95°C. The specific heat of the oil is $c_h$ = 2100 J/kg K and the specific heat of the water is $c_c$ = 4200 J/kg K.

(a) Determine the heat transfer rate in the heat exchanger and the oil outlet temperature. **(6 points)**

(b) Could the same water outlet temperature be attained if the heat exchanger was operated in a parallel flow configuration? Why? **(3 points)**

(c) We know the effectiveness (ε) and NTU are two key terms in the "effectiveness-NTU method". Please define and calculate the values of ε and NTU for the aforesaid counterflow heat exchanger system. **(12 points)**

$$NTU = \frac{1}{C_r - 1}\ln\left(\frac{\varepsilon - 1}{\varepsilon C_r - 1}\right)$$

where $C_r$ is the ratio of minimum heat capacity rate and maximum heat capacity rate.

(d) If the overall heat transfer coefficient U is 300 $W/m^2$ K, calculate the required surface area of the aforesaid heat exchanger. **(3 points)**

6. An <u>incompressible laminar flow</u> exists between two parallel walls that are a distance of 2B apart. Assuming that the fluid properties are constants and the mean/average velocity is $\langle u \rangle$. If we consider a region far from the entrance, where the velocity and temperature profiles are fully developed. There is a constant heat flux into the fluid from one of the walls (top wall, at y = 2B) and the other wall (bottom wall, at y = 0) is insulated.

(a) List all the assumptions that you would use for simplifying the Equation of continuity and Equations of motion (or Navier-Stokes equations) (see below) and list all the boundary conditions that you would use for solving the problem **(5 points)**.

(b) Please show that the steady-state velocity distribution is:

$$\boxed{u(y)=\frac{1}{2\mu}\left(-\frac{dp}{dx}\right)(2By-y^2)=\frac{3\langle u\rangle}{2B^2}(2By-y^2)}$$ **(5 points)**

(c) Find the steady-state temperature profile in the fluid **(5 points)**

(d) Evaluate the Nusselt number where h and $k_f$ are the heat transfer coefficient and thermal conductivity of the fluid, respectively. **(5 points)**

**Hints:**

**1. Consider (1) the width is of unit length, (2) velocities in the y and z directions are negligible, and (3) temperature is independent of z.**

**2. You might need the following equations:**

**<u>Equation of continuity</u>:**

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho \upsilon)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

**<u>Navier-Stokes Equations</u>:**

x-component: $$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+\upsilon\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial x}+\rho g_x+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)$$

y-component: $$\rho\left(\frac{\partial \upsilon}{\partial t}+u\frac{\partial \upsilon}{\partial x}+\upsilon\frac{\partial \upsilon}{\partial y}+w\frac{\partial \upsilon}{\partial z}\right)=-\frac{\partial p}{\partial y}+\rho g_y+\mu\left(\frac{\partial^2 \upsilon}{\partial x^2}+\frac{\partial^2 \upsilon}{\partial y^2}+\frac{\partial^2 \upsilon}{\partial z^2}\right)$$

z-component: $$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+\upsilon\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{\partial p}{\partial z}+\rho g_z+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)$$

**<u>Thermal energy equation</u>:**

$$\rho C_p\left(u\frac{\partial T}{\partial x}+\upsilon\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)+\mu\Phi+\dot{q}$$

$$\mu\Phi=\mu\left\{\left(\frac{\partial u}{\partial y}+\frac{\partial \upsilon}{\partial x}+\frac{\partial w}{\partial x}\right)^2+2\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial \upsilon}{\partial y}\right)^2+\left(\frac{\partial w}{\partial z}\right)^2\right]\right\}$$