國立中正大學八十四學年度碩士班考試試題

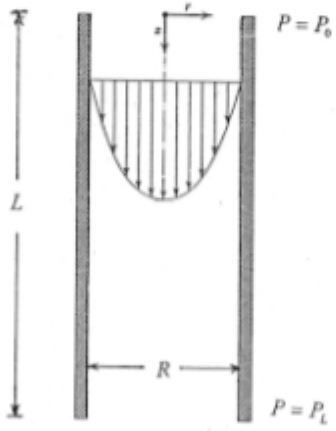
所　別：化學工程研究所　　科　目：輸送現象與單元操作

1. (20 points)
Consider a steady-state flow of an incompressible Newtonian fluid with constant ρ and μ through an infinitely long tube. Starting from the following equation of motion in cylindrical coordinates,

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

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

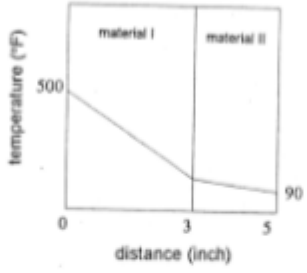
$$z\text{-component}\quad \rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial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



(1) Prove $-\frac{\partial P}{\partial z}=\frac{P_0-P_L}{L}$ (where $P=p-\rho gz$)
(2) Calculate the velocity profile of the flow.

2. (20 points)
Water flows through a packed bed at a superficial velocity of 1.0 ft/sec. The packed bed is filled with spheres of sugar of 5 mm diameter. With 0.41 bed void fraction, plug flow condition, and 0.0143cm/sec liquid side mass transfer coefficient, estimate the height of the packed bed required for the entering pure water to become 90% saturated with sugar. (Assuming constant size for the sugar spheres throughout the process)

3. (20 points)
A wall is made up of two layers of different materials having different thermal conductivities (26.1 and 0.04 Btu/hr-ft-°F). At steady state the temperature profiles appear thus:



(1) Which material has the higher thermal conductivity? Why?
(2) Estimate the heat transfer rate through the wall.
(3) Calculate the temperature at the interface of the two materials.

1

未完

國立中正大學八十四學年度碩士班考試試題

所　別：化學工程研究所　　科　目：輸送現象與單元操作

4. (20 %) Oil is to be extracted from meal by means of benzene, using a continuous countercurrent leaching equipment. The equipment is to treat 1000 kg of meal (based on completely exhausted solid) per hour. The untreated meal contains 380 kg of oil and 20 kg of benzene. The fresh solvent mixture contains 9 kg of oil and 591 kg of benzene. The exhausted solids are to contain 50 kg of unextracted oil. Experiments show that the solution retained depends on the concentration of the solution, as shown in the following relationship:

solution retained by the meal (kg/kg solid) = 0.5 + 0.2 x

where **x** is the mass fraction of oil (kg oil/kg solution) in the underflow.

(a) Find the oil concentration of the strong solution (extract) and the oil concentration of the solution adhering the extracted solid.
(b) Find the mass of solution leaving with the extracted meal and the mass of the strong solution.
(c) Find the number of stage required using the McCabe-Thiele diagram for leaching.
All quantities are given on an hourly basis.
(d) The equilibrium line is the 45° diagonal line, why?

5. (20 %) (a) Describe briefly the feature of "spray dryer" **or** "countercurrent air-heated rotary dryer" (chose one to answer!).
(b) A porous ceramic plate (100 lb) is dried from an initial moisture content of 0.12 lb/(lb dry solid) to a final moisture of 0.06 lb/(lb dry solid), using a hot air flowing across the drying surface. The area for drying is 10 ft². Obtain an equation for the total time of drying under constant drying conditions and then calculate the total drying time for this problem. The drying-rate curve for this material is shown in the following figure.
(c) What does the "**constant drying conditions**" mean?