94學年度__化學工程學___系（所）______________組碩士班入學考試

科目__輸送現象及單元操作__科目代碼___1401__共___5__頁第__1__頁 *請在試卷【答案卷】內作答

一、 The friction factor, f, of flow in tubes may be defined as

$$f = \frac{1}{4}\frac{D}{L}\frac{P_0 - P_L}{\frac{1}{2}\rho < v >^2}$$

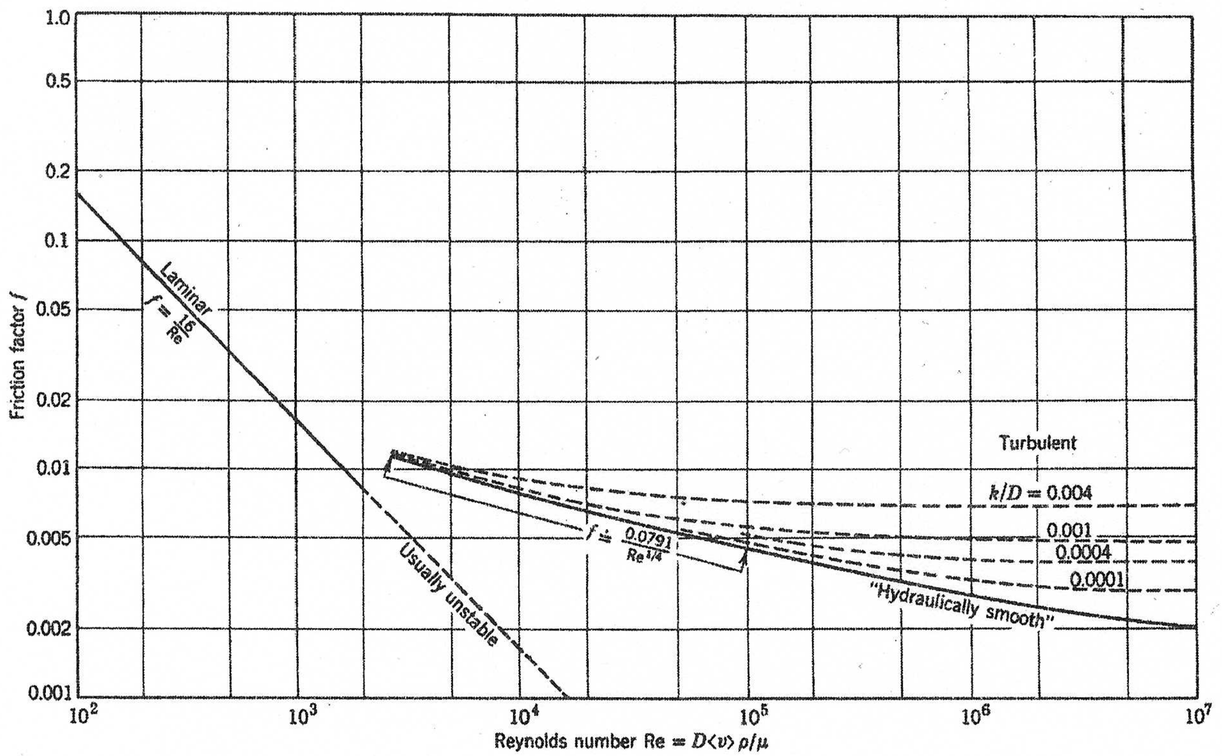
Here, $P_0 - P_L$ is the modified pressure drop ($P = p + \rho gh$) between point 0 and point L further down stream, D is the tube diameter, L is the considered tube length, ρ is the fluid density, and $< v >$ is the cross section averaged fluid velocity. [a-4%, b-3%, c-3%, d-10%]

(a) For laminar tube flow, $< v > = \frac{P_0 - P_L}{8\mu L} R^2$. Here, R is the tube radius and μ is the fluid viscosity. Show that f=16/Re .

(b) The term k/D appearing in the chart below is the relative roughness of the tube. Acording to the chart, does one need more powerful or less powerful pump to deliver fluid at the same rate in rougher tubes? Explain.

(c) To apply the chart to non-circular tubes operated at turbulent regime, what should one do?

(d) Explain how one can, based on the chart, determine D with all other operation conditions (P_0-P_L, L, <v>) and fluid parameters (ρ and μ) given? Do not consider the trial and error approach.



二、Consider the problem of laminar flow in a long pipe of circular cross section, with the pipe wall($r = R$) maintained at uniform temperature Tr. A Newtonian liquid of constant physical properties enters the pipe with uniform temperature $T1$. The thermal energy equation for temperature T can be simplified as

$$\rho C_P V_z \frac{\partial T}{\partial Z} = k\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)\right] \qquad (1)$$

Here we assume the flow is one-dimensional with velocity $V_z = V_z(\mathrm{r})$. ρ, C_P and k are density, heat capacity and thermal conductivity, respectively.

A. What are the other assumptions for Eqn(1) to be valid? (3%)

B. Can you write down the necessary boundary conditions for Eqn(1)? (3%)

C. Define an average temperature $<T>$ as

$$<\mathrm{T}> \equiv \frac{\int_0^R V_z T\, 2\pi r dr}{\int_0^R V_z\, 2\pi r dr} = \frac{\int_0^R V_z\, 2\pi r T dr}{Q} \qquad (2)$$

Here Q is the volumetric flow rate. What is the physical meaning of $<T>$? (2%)

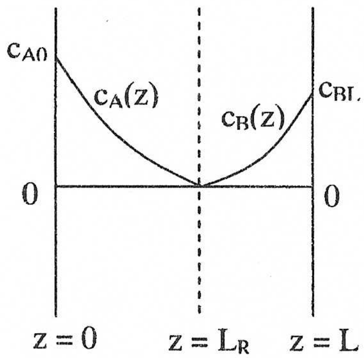
D. Multiply both sides of Eqn(1) by rdr, introduce $<T>$ and perform the integration from 0 to R, what is the final equation you have? (5%)

E. Define a heat transfer coefficient h as

$$-k\frac{\partial T}{\partial r}\Big|_R = \mathrm{h}[<T> - Tr] \qquad (3)$$

Introduce Eqn(3) into the final equation in D and perform the integration to find an explicit expression of $<T>$.(7%)

三、Imagine a film of stagnant liquid in which a chemical species B of concentration c_B is dissolved. At the surface z = 0 a concentration c_{A0} of another species A is maintained, as shown in the figure below. Species A and B will diffuse according to different diffusion coefficients, which are denoted as D_A and D_B, and profiles $c_A(z)$ and $c_B(z)$ will be established under steady state. Now suppose further that species A and B will react very fast when they meet, i.e., when one molecule of A meets one molecule of B, they react and disappear (as a product molecule of the reaction). In this case, the profiles of $c_A(z)$ and $c_B(z)$ will appear as those sketched in the figure. The plane ($z = L_R$) at which A and B meet and react is called the "reaction front".



Obtain the expressions for the followings:

(a) The location of the reaction front, L_R (8%)

(b) Concentration profiles, $c_A(z)$ and $c_B(z)$ (8%)

(c) The molar flux of species A, N_{Az}. (4%)

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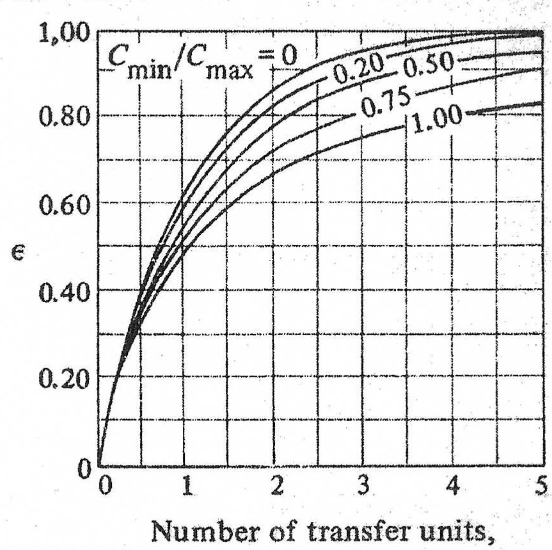
科目__輸送現象及單元操作__科目代碼___1401__共___5__頁第__4__頁 *請在試卷【答案卷】內作答

四、A method called the heat-exchanger effectiveness ε is often used to calculate the heat-transfer rate q for a double-pipe heat exchanger, which does not involve any of the outlet temperatures.

(a) Explain the terms of "heat-exchanger effectiveness" and "number of transfer unit, *NTU*). (6%)

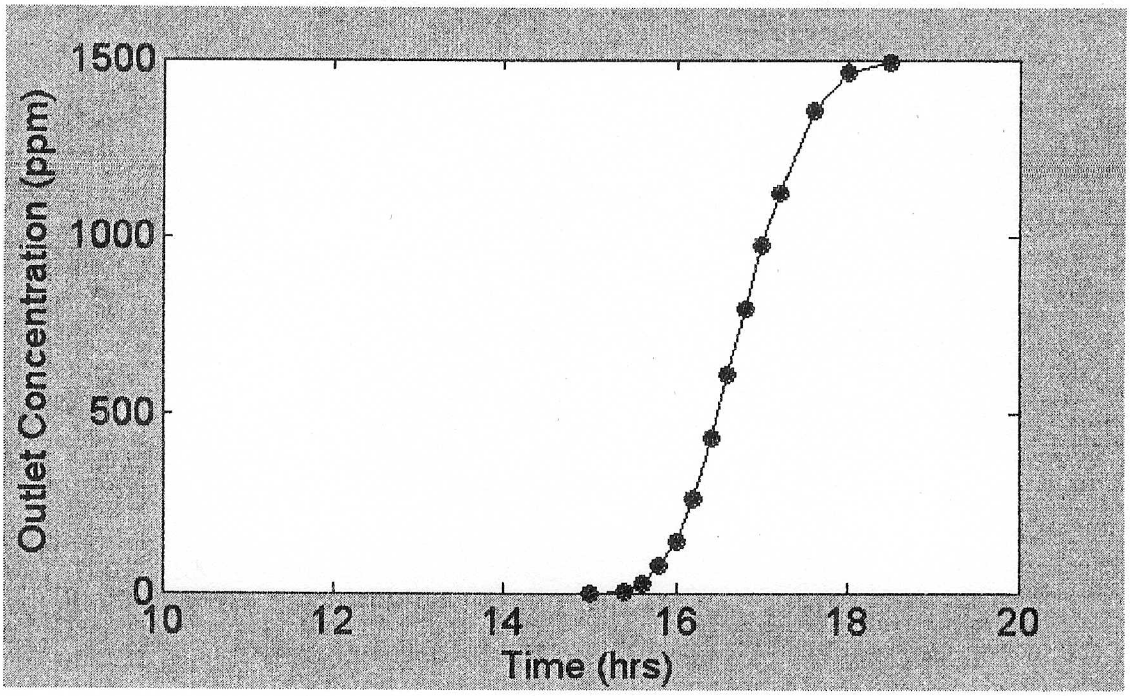
(b) Derive a heat transfer equation for this double-pipe heat exchanger incorporated with heat-exchanger effectiveness ε. [C_{min} (= mc_p): minimum heat capacity; T_{Hi}: inlet temperature of hot fluid; T_{Ci}: inlet temperature of cold fluid]. (7%)

(c) Water (c_p = 4.192 kJ/kg・K) flowing at a rate of 0.667 kg/s enters a counter-flow heat exchanger at 308 K and is heated by an oil stream entering at 383 K at a rate of 2.85 kg/s (c_p = 1.89 kJ/kg・K). The overall U = 300 W/m^2・K and the area A = 15.0 m^2. Calculate the number of transfer unit, the heat-transfer rate and the exit water temperature. (7%)



Heat-exchanger effectiveness ε for a counter-flow exchanger

五、Air containing a pollutant A is to be purified by fixed-bed adsorption using activated carbon. In a bench scale experiment, an adsorption column 0.1 m in length and 0.01 m in diameter was used. The concentration of A at the outlet of the column as a function of time was measured and given in the follow figure:



Estimate the following

(a) Break-through time(3%)

(b) Saturation time(3%)

(c) Length of the unused bed(4%)

Suppose the actual volumetric flow rate of air to be treated is 100 times the current flow rate, and a fix-bed 1 m in length and 1 cm in diameter is used, calculate the operation time that column can be used before it needs to be regenerated. (10%)