國立中央大學108學年度碩士班考試入學試題

所別： 化學工程與材料工程學系 碩士班 甲組(一般生) 共4頁 第1頁

科目： 輸送現象與單元操作

本科考試可使用計算器，廠牌、功能不拘

申論題及導論題

1. (20%, 2% each) **Friction factor for tube flow**

The friction factor (f)-Reynolds number (Re) relationships for a Newtonian fluid flowing through smooth conduits or commercial rough conduits are summarized in **Figure A.** The friction factor and Reynolds number are defined as follows as the conducts are circular:

$$f = \frac{1}{4}\left(\frac{D}{L}\right)\left(\frac{P_0 - P_L}{\frac{1}{2}\rho\langle u\rangle^2}\right) \quad (1\text{-}1)$$

$$\mathrm{Re} = D\langle u\rangle\rho/\mu \quad (1\text{-}2)$$

And D, $\langle u\rangle$, ρ, μ, P_0-P_L, and L are tube diameter, mean velocity, liquid density, liquid viscosity, pressure drop, and tube length, respectively. The symbol k in Figure A is the height (roughness) of the protuberances. Answer the following equations briefly.

(a) What is the physical meaning of Reynolds number?

(b) What is the physical meaning of friction factor?

(c) If the tubes are noncircular, what the Reynolds number (equation 1-2) and friction factor (equation 1-1) become?

(d) Why does the friction factor monotonously decrease with increases in Reynolds number? Does it indicate a reduction of shear stress when fluid velocity is increased?

(e) Why in laminar flow region friction factor is inversely proportional to Reynolds number?

(f) Why in turbulent flow region friction factor is independent of Reynolds number?

(g) Why in laminar flow region friction factor is independent of the roughness?

(h) Why in turbulent flow region friction factor increases with increases in wall surface roughness of conduits?

(i) Explain why in the turbulent flow region, the friction factor is affected by dimensionless group k/D, but not by k?

(j) What is the physical meaning of "hydraulic smooth" limit in **Figure A**?

注意:背面有試題

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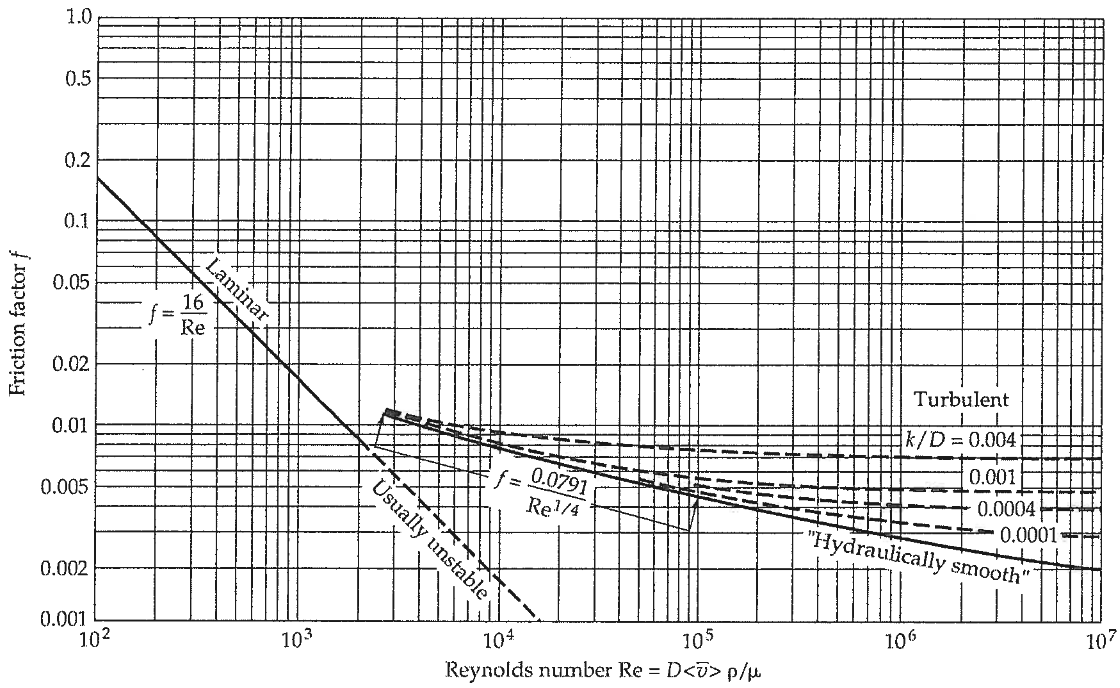


Laminar: $f = \dfrac{16}{\mathrm{Re}}$ $\quad \mathrm{Re} < 2100$

turbulent: $f = \dfrac{0.0791}{\mathrm{Re}^{1/4}}$ $\quad 2100 < \mathrm{Re} < 10^5$ Blasius formula

Turbulent for rough pipes: $\dfrac{1}{\sqrt{f}} = -3.6\log_{10}\left[\dfrac{6.9}{\mathrm{Re}} + \left(\dfrac{k/D}{3.7}\right)^{10/9}\right]$ $\quad 4\times10^4 < \mathrm{Re} < 10^8$, $0 < k/D < 0.05$ Haaland equation

Figure A: Friction factor for tube flow

2. (10%, 2% each) **Stream Functions and Velocity Potential**

Comment and discuss briefly the following statements (and/or equations). Also please indicate whether each of these statements (and/or equations) is correct or incorrect.

(a) Stream functions (ψ) can be used to resolve the 2-dimensional flow problems for both compressible and incompressible fluids.

(b) Velocity potential (Φ) is only used to solve 2-dimensional irrotational flow problems, and invalid for solving 3-dimensioanl irrotational flow.

參考用

(c) If the velocity potential is $\Phi = (5/3)x^3 - 5xy^2$, then its corresponding stream function is $\psi = 5x^2y$.

(d) The function, $F(x, y) = u_\infty L[x^2/L^3 - (3xy^2)/L^3]$, can be used as velocity potential to solve irrotational flow problems

(e) The stream function can be used in solving both viscous and ideal (or inviscid) flow problems.

3. (10%)

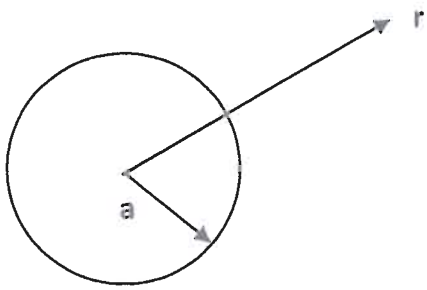
(a) (4%) Write down the definitions of Nusselt number and Biot number. What is the difference between Nusselt number and Biot number?

(b) (6%) What dimensionless number(s) influence Nusselt number? Please also write down the definition of the dimensionless number(s).

4. (20%) **Heat Conduction in an Annulus**

Heat is flowing through an annular wall of inside radius r_0 and outside radius r_1. The temperature at $r = r_0$ is T_0 and the temparature at $r = r_1$ is T_1. The thermal conductivity varies linearly with temperature from k_0 at T_0 to k_1 at T_1. Develop an expression for the heat flow through the wall.

5. (40%) When a single-component liquid droplet evaporates into air as in the operation of spray-drying, or when a solid drug granule, modeled as a single-component sphere, dissolves in a liquid as in drug dissolution, we can construct a simple model of the diffusive transport that occurs between the object and the surrounding fluid.



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You may assume: (1) The sphere contains a pure solid component A; therefore, you need to consider the mass transport process only in the surrounding fluid, (2) the fluid is unbounded in extent and quiescent. It contains only the diffusing species A, and a non-transferring species B, (3) the motion of arising from diffusion can be neglected. This requires that either the mixture in the fluid be dilute in species A, consisting primarily of the non-transferring species B, or that the rate of mass transport be small, (4) the problem is spherically symmetrical, there are no gradients either in the polar coordinates or the azimuthal angular coordinates, (5) after an initial transient, a steady state is assumed to prevail. The change in size of sphere due to mass transfer occurs on a time scale that is very large compared with the time scale for the diffusion process for a given radius of the sphere to reach steady state, and (6) there are no chemical reactions.

Please calculate:

(a) (5%) the flux of species A, $N_{Ar}(r)$,

(b) (5%) the molar rate of mass transfer at the surface of the sphere, W_A,

(c) (5%) the rate of change of the radius of the sphere with time, $a(t)$, assuming the mole fraction of species A in the fluid at the interface is X_{A1}, the radius at time zero is a_0, the molecular weight of A be M_A, and the density of the sphere be ρ. What is the advantage of making a_0 very small by nanotechnology?

(d) (5%) the flux of species A, $N_{Ar}(a_0)$, at the surface of a sphere of radius a_0,

(e) (5%) the time estimated for the diffusion process around a sphere of radius a_0,

(f) (5%) the time estimated for the sphere to completely dissolve in the fluid,

(g) (5%) what is the ratio of the two time scales calculated in Parts (e) and (f)?

(h) (5%) what should the ratio (i.e. the dimensionless group) in Part (g) become to make Assumption (5) in the problem statement valid?