國立臺北科技大學

九十三學年度化學工程系碩士班入學考試

單元操作與輸送現象試題

填准考證號碼

注意事項：

1. 本試題共五題，配分共 100 分。
2. 請按順序標明題號作答，不必抄題。
3. 全部答案均須答在答案卷之答案欄內，否則不予計分。

1. A 60 cm^2 filter cake of 6 cm thick is dried from both sides with air. The air at 1 atm and 49°C flows parallel to the faces of the cake at a velocity of 0.7 m/s. The dry density of the cake is 1922.4 kg/m^3. The equilibrium moisture content is assumed negligible and the critical moisture content is 0.09. Assume the drying rate in the falling-rate period is proportional to the free moisture content (a straight line through the origin). The solid surface temperature during constant rate period is 27°C. The latent heat of vaporization is assumed to be 2440 kJ/kg.
The heat transfer coefficient at the surfaces of the cake can be calculated as follows:

$$h = 59.83G^{0.8}$$

where G is the mass velocity of air in $kg/(hr)(m^2)$ and h in $J/(hr)(m^2)(°C)$.

(a) What is the drying rate during the constant-rate period? (13%)

(b) Compute the time required to dry the material from an initial moisture content of 0.20 to 0.02. All the moisture contents here are based on the dry basis. (7%)

2. A dilute solution of hydrochloric acid is cooled at the tube-side of a double pipe heat exchanger from 40°C to 20°C. Cooling water flows countercurrently to the acid solution, entering the annular space of the exchanger at 10°C and leaving at 20°C. The heat duty of the heat exchanger is 15 kW. To avoid excessive corrosion, hastelloy (nickel-base alloys) with a thermal conductivity of 10 W/(m)(K) is used for the central pipe, which has an inside diameter of 20 mm and a wall thickness of 2 mm. The film coefficients for hydrochloric acid solution and cooling water are 2000 $W/(m^2)(K)$ and 3000 $W/(m^2)(K)$, respectively.

(a) Calculate the length of the heat exchanger if fouling is assumed to be negligible. (13%)

(b) Iron oxide particles from upstream corrosion form a deposit at the pipe inside surface with a fouling resistance of 0.5 $(m^2)(K)/(kW)$. On the cooling water side, microbacterial growth creates a slimy deposit of 0.1 mm thickness and a thermal conductivity of 1 W/(m)(K). Determine the reduction in heat duty. (7%)

3. In the catalytic cracking of hydrocarbons, hot gases of heavy hydrocarbons A diffuse to the catalytic surface where they are cracked. The product P diffuses back into the gas stream. A kinetic investigation indicated compound A is cracked according to

$$A \rightarrow 2P$$

The reaction takes place on a spherical catalyst particle of radius R at a very rapid rate that diffusion in the stagnant film surrounding the particle controls the rate of the reaction. Consider one boundary condition that at a very far distance from the catalyst particle, the concentration of A is in the bulk gas stream.

(a) Determine the concentration profile for A as a function of radius outward from the catalyst particle. (15%)
(b) Develop an expression for the cracking reaction rate. (5%)

4. A 2-in.-OD stainless steel tube 10 ft long has 16 longitudinal fins spaced around its outside surface as shown in Figure 1. The fins are 1/16 in. thick and extend 1 in. high from the outside surface of the tube. The thermal conductivity of the tube is 9.4 Btu/(hr)(ft)(°F). The outside surface of the tube wall is at 250°F, the surrounding air is at 80°F, and the convective heat transfer coefficient is 18 Btu/(hr)(ft^2)(°F). Determine:
(a) the fin efficiency. (10%)
(b) the heat transfer rate for the finned pipe. (10%)

5. An aqueous nitric acid solution (ρ =1068 kg/m^3; viscosity μ = 0.00106 kg/(m)(s)) is to be pumped from a storage tank through 278 m length of steel pipe to a discharge point 57.4m above the pump outlet. The inside diameter is 3.20 cm and absolute roughness is 0.0035 mm for the pipe. The pump inlet is 5.60m below the liquid surface in the storage tank and the pump is 80 percent efficient. The Fanning friction factor is given in Figure 2. Calculate:
(a) the horsepower of the pump required to deliver the acid solution at a rate of 2.35 kg/s. 1 horsepower = 746 J/s. (13%)
(b) the percentage increase in power of the pump to maintain the flow rate of 2.35 kg/s when corrosion has increased the absolute roughness of the pipeline to 0.050 mm. (7%)

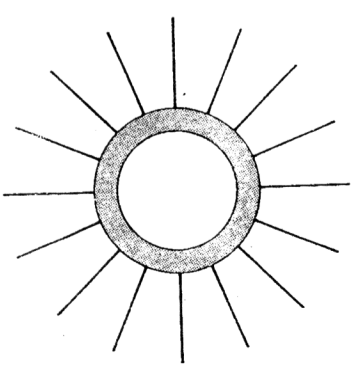

Figure 1

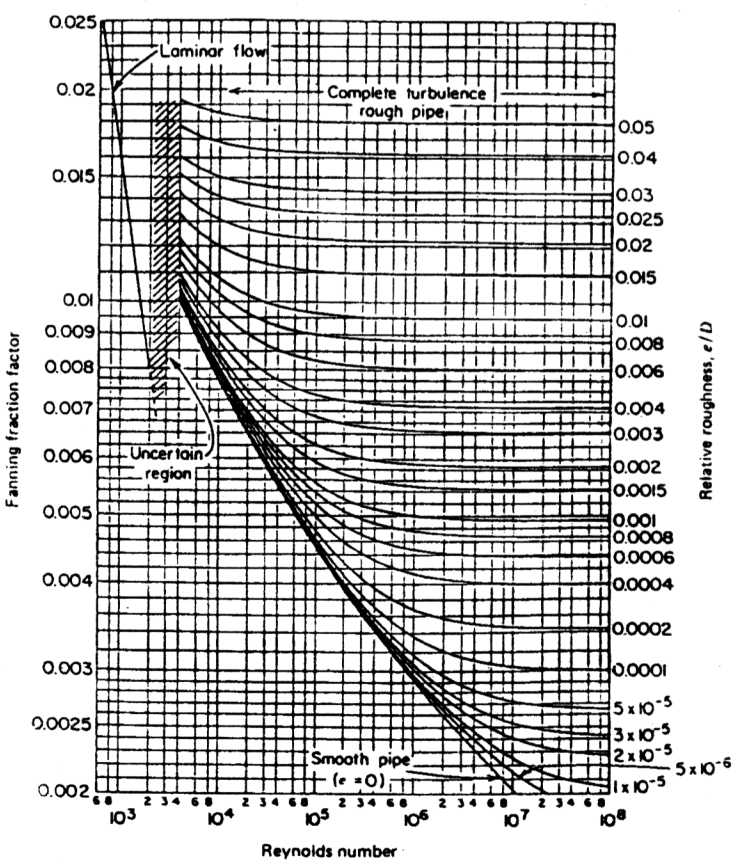

Figure 2