UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE TATI (UCTATI)

FINAL EXAMINATION QUESTION BOOKLET		
COURSE CODE	:	BCE 3104
COURSE TITLE	:	UNIT OPERATIONS 2
SEMESTER/SESSION	:	SEM 1 / 2023 2024
DURATION	:	3 HOURS

Instructions:

1. This booklet contains **5** questions. **Answer all questions**.
2. All answers should be written in the **Final Examination Answer Booklet**.
3. Write legibly and draw sketches wherever required.
4. If in doubt, please raise up your hands and ask the invigilator.
5. Students are allowed to bring notes, formula, etc in **3 pieces of A4 paper.**

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

THIS BOOKLET CONTAINS 5 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

Figure 1.1 represent a wet solid drying curve. The wet solid is to be dried from X_1 = 0.4 kg H_2O/kg dry solid to X_2 = 0.1 kg H_2O/kg dry solid. The drying area is 15 m^2 and the weight of dry solid is 150 kg. Value at point C is (0.195, 1.51) and value at point D is (0.07, 0.7).

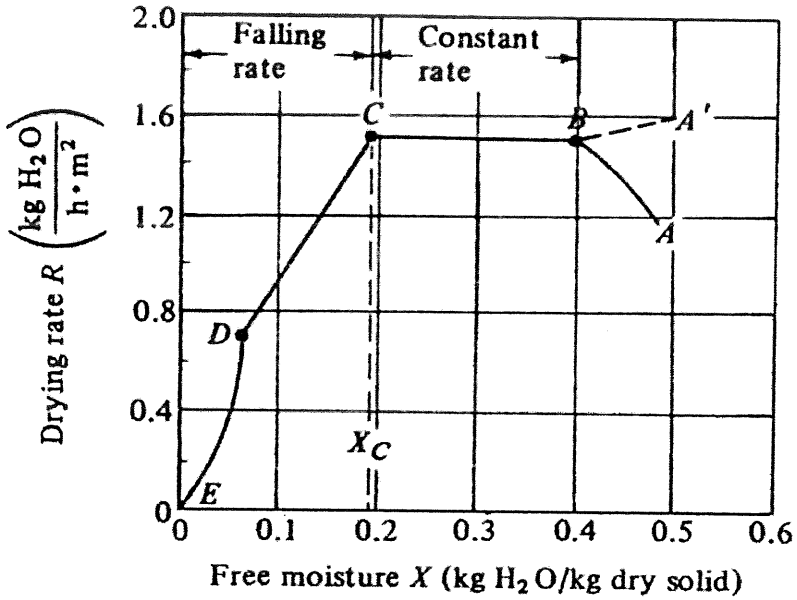

Figure 1.1: Drying rate versus free moisture of a wet solid

a) Give the value of X_c and R_c from the curve.

(2 marks)

b) Using analytical formula predict the time of drying for the constant rate region. Then by using numerical integration technique, predict the time of drying for the falling rate region. Use $\Delta X = (X_c - X_2)/3$ for your numerical integration for falling rate region.

(15 marks)

c) Calculate the total drying time from X_1 to X_2.

(3 marks)

QUESTION 2

Compute the minimum and maximum fluidization velocity for the following packed bed. The following equations can be used to calculate the minimum and maximum fluidization velocity of a fluid in the packed bed.

$$(\rho_p - \rho_f)\, g = 150\frac{\mu_f V_{mf}\,(1-\varepsilon_{mf})}{\phi_s^2 D_p^2 \varepsilon_{mf}^3} + 1.75\frac{\rho_f V_{mf}^2}{\phi_s D_p \varepsilon_{mf}^3}$$

$$V_{max} = \frac{g D_p^2\,(\rho_p - \rho_f)}{18\mu_f}$$

Particular of the packed bed:

Gravity acceleration, g = 9.81 m/s^2

ε_{mf} = 0.40

Fluid viscosity, μ = 0.00002 kg/(m.s) or Pa.s

Average particle diameter, D_p = 0.001 m

Sphericity, ϕ = 0.7

Fluid density, ρ_f = 1000 kg/m^3

Particle density, ρ_p = 2500 kg/m^3

(14 marks)

QUESTION 3

Calculate the pressure drop across the above packed bed (in Question 2). Ergun equation is used to calculate the pressure drop across a packed bed:

$$f_p = \frac{150}{Re_p} + 1.75 \qquad f_p = \frac{\Delta p}{L}\frac{D_p}{\rho V_s^2}\left(\frac{\varepsilon^3}{1-\varepsilon}\right) \qquad Re_p = \frac{D_p V_s \rho}{(1-\varepsilon)\mu}$$

Additional information:

Fluid mass flow = 1.5 kg/s

Packed bed diameter = 1.2 m

Packed bed length = 4.0 m

(16 marks)

QUESTION 4

A filtration is carried out at constant pressure and the filter media resistance is negligible. The laboratory filtration data for the solid particle is as follows:

Cake weigh = 200 grams.

Cake depth = 15 cm.

Cake volume = 500 cm^3.

ΔP = 30 psi.

Filter diameter = 10 cm.

Filtration time = 120 min.

Note: 1 in^3 = 16.39 cm^3

a) Give two examples of filtration in industries.

(2 marks)

b) Predict the number of frames (50 in x 50 in x 2 in thick) needed for a plate and frame press based on the laboratory data to produce 150 kg solid.

(8 marks)

c) Evaluate the time required for filtering 150 kg solid with applied ΔP = 10 psi.

(10 marks)

QUESTION 5

A reverse osmosis (RO) membrane is to be used at 25°C for a NaCl feed containing 2.5 g NaCl/L (2.5 kg NaCl/m^3, ρ = 1007 kg/m^3).The water permeability constant, A_w is 5 x10^{-4} kg/(s.m^2.atm) and the solute permeability constant is 4 x 10^{-7} m/s. The ΔP used across the membrane is 35 atm. Table 4.1 can be used to predict the osmotic pressure of the solutions. Molecular weight of NaCl is 58.45 g/mol.

Table 4.1: Osmotic pressure of NaCl solutions.

Sodium Chloride Solutions

$\frac{g\ mol\ NaCl}{kg\ H_2O}$	*Density* (kg/m^3)	*Osmotic Pressure* (*atm*)
0	997.0	0
0.01	997.4	0.47
0.10	1001.1	4.56
0.50	1017.2	22.55
1.00	1036.2	45.80
2.00	1072.3	96.2

a) Estimate concentration of NaCl in the permeate.

(20 marks)

b) Predict the water flux across the RO membrane.

(5 marks)

c) Determine solute rejection, R.

(5 marks)

---------- **END OF QUESTIONS**----------