UNIVERSITY COLLEGE TATI (UCTATI)

FINAL EXAMINATION QUESTION BOOKLET

COURSE CODE	:	BCE 3104 571
COURSE TITLE	:	UNIT OPERATIONS 2
SEMESTER/SESSION	:	SEM 1 / 2024 2025
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 **2 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

A drying curve of a wet solid is represented in Figure 1.0. The drying area is 10 m^2 and the weight of dry solid is 200 kg. The wet solid is to be dried from X_1 = 0.4 kg H_2O/kg dry solid to X_2 = 0.15 kg H_2O/kg dry solid. Value at point C is (0.195, 1.510) and value at point D is (0.070, 0.700).

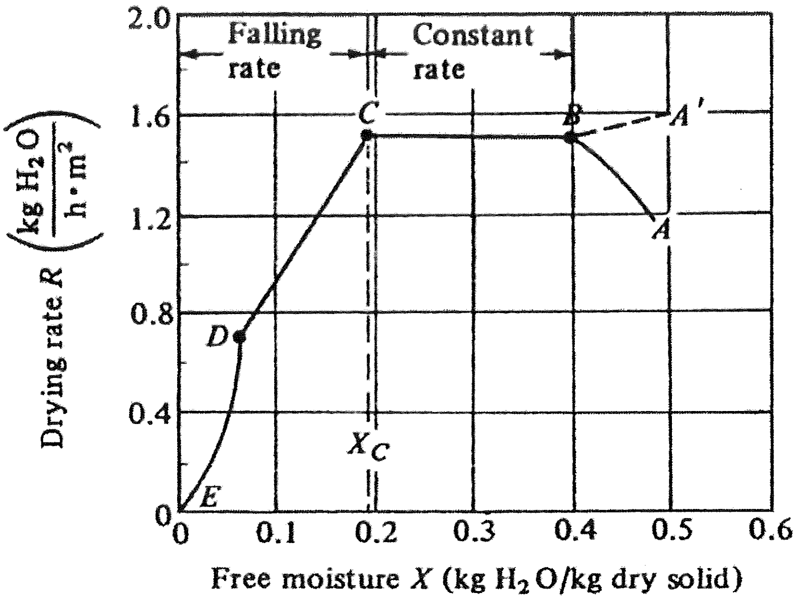

Figure 1.0 : Drying rate versus free moisture of a wet solid

a) Give the value of X_c and R_c.

(2 marks)

b) Predict the drying time for the constant rate region using <u>analytical formula</u>. Then by using <u>numerical integration</u> 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 a packed bed using the following equation.

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

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

Particular of the packed bed:

Gravity acceleration, g = 9.81 m/s^2

ε_{mf} = 0.50

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

Average particle diameter, D_p = 0.002 m

Sphericity, ϕ = 0.8

Fluid density, ρ_f = 1000 kg/m^3

Particle density, ρ_p = 2700 kg/m^3

(14 marks)

QUESTION 3

Calculate the pressure drop across the packed bed in Question 2 using the following Ergun equation:

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

Additional information:

Fluid mass flow = 1.2 kg/s

Packed bed diameter = 1.0 m

Packed bed length = 3.0 m

(16 marks)

QUESTION 4

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

Cake weight = 300 grams.

Cake depth = 13 cm.

Cake volume = 550 cm^3.

ΔP = 35 psi.

Filter diameter = 10 cm.

Filtration time = 100 min.

Note: 1 in^3 = 16.39 cm^3

a) Give two filtration examples in industries.

(2 marks)

b) Predict the number of frames (60 in x 60 in x 3 in thick) needed for a plate and frame press based on the laboratory data to produce 500 kg solid.

(8 marks)

c) Evaluate the time required for filtering 500 kg solid with applied ΔP = 15 psi.

(10 marks)

QUESTION 5

An NaCl feed containing 2.5 g NaCl/L (2.5 kg NaCl/m^3, ρ = 1007 kg/m^3) at 25°C is fed into a reverse osmosis (RO) membrane. 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. Use Table 5.0 to predict the osmotic pressure of the solutions. Molecular weight of NaCl is 58.45 g/mol.

Table 5.0: 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 the NaCl concentration of the permeate.

(20 marks)

b) Predict the water flux across the membrane.

(5 marks)

c) Determine R, the solute rejection.

(5 marks)

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