NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF APPLIED CHEMISTRY

PRINCIPLES OF PROCESS ENGINEERING

SCH 2218

Second Semester Examination Paper

MAY 2016

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Examiner's Name: Engr S Mudono

INSTRUCTIONS

1. Answer any four questions
2. Each question carries 25 marks
3. Use of calculators is permissible

MARKS ALLOCATION

QUESTION	MARKS
1.	**25**
2.	**25**
3.	**25**
4.	**25**
5.	**25**
6.	**25**
TOTAL POSSIBLE MARKS	**100**

QUESTION 1

A. Define what a fluid is and explain how fluids are classified. **[5]**

B. Calculate the loss of head due to friction and the power required to maintain flow in a horizontal circular pipe of 60 mm diameter and 750 m long when milk (SG = 1.6 and μ = 2.24 x10^{-3} N.s/m^2) flows at a rate of:

i. 4.5 liters/min **[10]**

ii. 30 liters/min **[10]**

$$\frac{\Delta P}{\rho g} = h_f = \frac{4fLv^2}{2gd}, f = \frac{16}{Re}(laminar)$$

$$f = 0.08\,Re^{-0.32}(turbulent)$$

QUESTION 2

A. Define molecular diffusion and with the aid of a well labeled diagram explain how molecular diffusion manifests. **[10]**

B. Methane diffuses at steady state through a tube containing helium. At point 1, the partial pressure of methane is P_{A1} = 55 kPa and at point 2, 0.03 m apart, P_{A2} = 15 kPa. The total pressure is 101.32 kPa, and the temperature is 298 K. At this pressure and temperature, the value of diffusivity is 6.75 x $10^{-5}m^2/s$. R = 8.314 kPa.m^3/mol.K

i. Calculate the flux of CH_4 at steady state for equimolar counter diffusion. **[5]**

ii. Calculate the partial pressure at a point 0.02 m apart from point 1. **[2]**

C. Desorption of a component A from an aqueous solution into an air stream is taking place in a mass transfer tower at a certain operating temperature and pressure. At a particular point in the tower, analysis report reveals:

$P_{A,G}$ = 12 mmHg; $C_{A,L}$ = 4 kmol/m^3; K_G = 0.269 kmol A/(h.m^2.atm)

If Henry's law is satisfied by the system and 56 % of the total mass transfer resistance is encountered in the gas film, calculate:

i. Gas – film coefficient, k_G **[2]**

ii. Liquid –film coefficient, k_L **[2]**

iii. Molar flux N_A **[4]**

H = 7.5 x10^{-3} atm/(mol a/m^3. soln)

QUESTION 3

A. Explain the mechanisms for heat transfer. [**9**]

B. The walls of an oven comprise of three layers:

15cm outer brick work (k = 0.75 W/m°C), 1.25 cm inner wooden panelling (k = 0.2 W/m°C), and 7.5 cm intermediate layer of insulating material. The insulation layer is slated to offer resistance twice the thermal resistance of brick work. If the inside and outside temperatures of the composite wall are 1200°C and 30°C, respectively, determine the rate of heat loss per unit area of the wall and the thermal conductivity of the insulating material. [**12**]

C. Determine the thermal radiation heat loss per unit area from the surface of a bakery oven with inside temperature is 220°C. Assume that the surface behaves like a blackbody.

$\sigma = 5.699 \times 10^{-8}$ W/m^2.K^{-4} **[4]**

QUESTION 4

A. Cooking oil (C_p = 2 090J/kg.K) flowing at a rate of 0.5 kg/s is cooled by allowing it to exchange energy with water in a heat exchanger. The oil enters and leaves the heat exchanger at 375 K and 350 K, respectively. Water (C_p = 4.18 kJ/kg.K) at 290 K is available in sufficient quantity to allow 0.201 kg/s to be used for cooling purposes. With the aid of labelled sketch diagrams determine the required heat transfer area for:

i. Counter flow **[10]**

ii. Parallel flow **[6]**

U = 250 W/m^2.K

B. A solution of 25 % edible oil in oil seed cake is to be extracted with hexane in a five-stage co-current unit. If 25 kg of hexane/100 kg feed is used, find the amount of edible oil extracted and find the final concentration. The equilibrium relation is given by (kg edible oil/kg hexane = 2.20 (kg edible oil/kg oil seed cake) **[9]**

$$X_n = \left[\frac{A}{(A + Bm)}\right]^n X_f$$

QUESTION 5

A. With the aid of a well labeled diagram describe the rate of drying. **[10]**

B. A wet solid is dried from 25 % moisture content under constant drying condition for 15 ks (417 hr.). If the critical and equilibrium moisture content are 15 % and 5 %, respectively, how long will it take to dry the solid from 30 % to 8 % moisture content under same conditions? **[10]**

C. Briefly explain the freezing of food by fluidization method. **[5]**

QUESTION 6

A. Briefly discuss the factors affecting the rate of leaching **[10]**

B. 4 kg/s of liquor with 10 % solids is fed at 294 K to the first effect of a triple effect unit. Liquor with 50 % pressure is to be drawn from the third effect, which is at a pressure of 13 kN/m^2. The liquor will be assumed to have a specific heat capacity of 4.18 kJ/kg.K and to have no BPR. Saturated dry steam at 205 kN/m^2 is fed to the heating element of the first effect and the condensate is removed at the steam temperature in each effect. If the three units are to have equal areas, estimate:

i. Area **[3]**

ii. Temperature **[4]**

iii. Temperature difference and **[3]**

iv. Steam consumption **[5]**

END OF EXAMINATION QUESTION PAPER!!!!!!!