Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	MASS TRANSFER
COURSE CODE	:	BNQ 20303
PROGRAMME CODE	:	BNN
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **TWELVE (12)** PAGES

Q1 Answer the following question based on the mass transfer application problems:

(a) In the diffusion coefficient experiment, students need to check the diffusion rate for three different salt molar concentrations (M) starting from the lower concentration 1M, followed by 2M, and 4M. The output should show an increase in conductivity with the increase in salt concentration. However, the result shows that the 1M salt gives the highest conductivity reading. Discuss this situation by providing the possible reason and solution to this problem.

(4 marks)

(b) In the membrane separation experiment, the membrane resistance needs to be determined before further membrane study is conducted. Explain the detrimental effect if the membrane resistance fails to be examined.

(4 marks)

(c) In a spray dryer experiment, 100 g of milo powder was dissolved in 500 ml hot water. The milo solution was inserted into the spray dryer unit at 200 °C. After 10 minutes, the solution was dried, and the final product collected was 65 g of milo powder.

(i) Discuss why the product did not have the same amount as the initial milo powder (100 g).

(3 marks)

(ii) Calculate the efficiency of the spray dryer in percentage (%).

(3 marks)

(d) There are two methods to obtain salt from a salt solution in a crystallization experiment.

(i) State the **TWO (2)** methods mentioned above.

(2 marks)

(ii) Draw a flow chart showing how you experimented, from weighing the salt until achieving the final product for both methods listed in question **1(d)(i)**.

(4 marks)

(e) A final-year project student needs to extract bioactive compounds from selected plants. After the extraction process, he needs to isolate those compounds from plant matrices.

(i) Propose **ONE (1)** method for isolating the compounds.

(1 marks)

(ii) Explain how the isolation process applies.

(4 marks)

Q2 Helium gas is stored at 293 K and 500 kPa in a 1 cm thick, 2 m inner diameter spherical tank made of fused silica (SiO_2). The area where the container is located is well-ventilated. The solubility of helium in fused silica at 293 K and 500 kPa is 0.00045 kmol /m^3.bar. The D_{AB} of helium in fused silica at 293 K is 4×10^{-14} m^2/s and the molar mass of helium is $M = 4$ kg/kmol.

(a) Identify the process mentioned above and determine **FOUR (4)** factors that influence the process.

(5 marks)

(b) Draw and label the process mentioned above.

(5 marks)

(c) Calculate helium's molar concentration at the container's inner surface, C_{A1}.

(5 marks)

(d) Determine the mass flow rate of helium in kg/week.

(10 marks)

Q3 Pure water at 26.1 °C flows at a velocity of 0.0305 m/s in a tube with an inside diameter of 6.35 mm. The tube is 1.829 m long, with the last 1.22 m having the walls coated with benzoic acid. The solubility of benzoic acid in water is 0.02948 kg mol/m^3. Assuming that the velocity profile is fully developed,

(a) Illustrate and label the diagram of the tube.

(5 marks)

(b) Calculate N_{Re}, N_{Sc} and ($W/D_{AB}\rho L$).

(10 marks)

(c) Calculate the average concentration of benzoic acid at the outlet where the properties used are $\mu = 8.71 \times 10^{-4}$ Pa.s, $\rho = 996$ kg/m^3, and $D_{AB} = 1.245 \times 10^{-9}$ m^2/s.

(10 marks)

Q4 A wet cylinder of agar gel at 278 K containing a uniform urea concentration of 0.1 kg mol/m^3 has a diameter of 30.48 mm and is 38.1 mm long with flat parallel ends. The diffusivity is 4.72×10^{-10} m^2/s.

(a) Sketch the situation mentioned above.

(5 marks)

(b) After 100 hours, the cylinder is immersed in turbulent pure water. By referring to **Figure APPENDIX C.1 and C.2, and Table APPENDIX C.1,** determine the concentration at the midpoint of the cylinder:

(i) For radial diffusion only.

(10 marks)

(ii) Diffusion occurs radially and axially.

(10 marks)

- END OF QUESTIONS -

APPENDIX A

Table APPENDIX A.1 FACTORS FOR UNIT CONVERSIONS

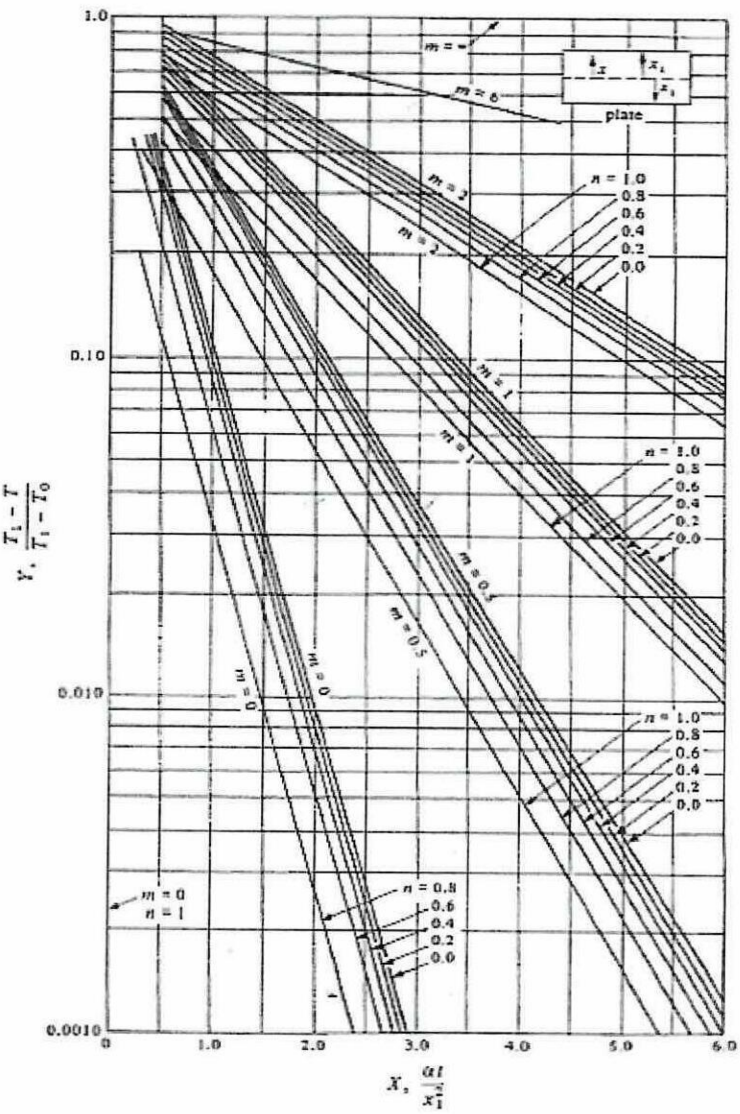
Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz
	1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 μm = 10^{10} Å
	1 m = 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile
	1 ft = 12 in = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 liters = 10^6 cm^3 = 10^6 ml
	1 m^3 = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt
	1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3 = 28.317 liters = 28317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f
	1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars
	1 atm = 1.01325×10^6 dynes/cm^2
	1 atm = 760 mmHg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/in^2 (psi)
	1 atm = 33.9 ft H_20 at 4°C = 29.921 inHg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h
	1 J = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 1.341×10^{-3} hp

APPENDIX B

Table APPENDIX B.1 GAS CONSTANT (R)

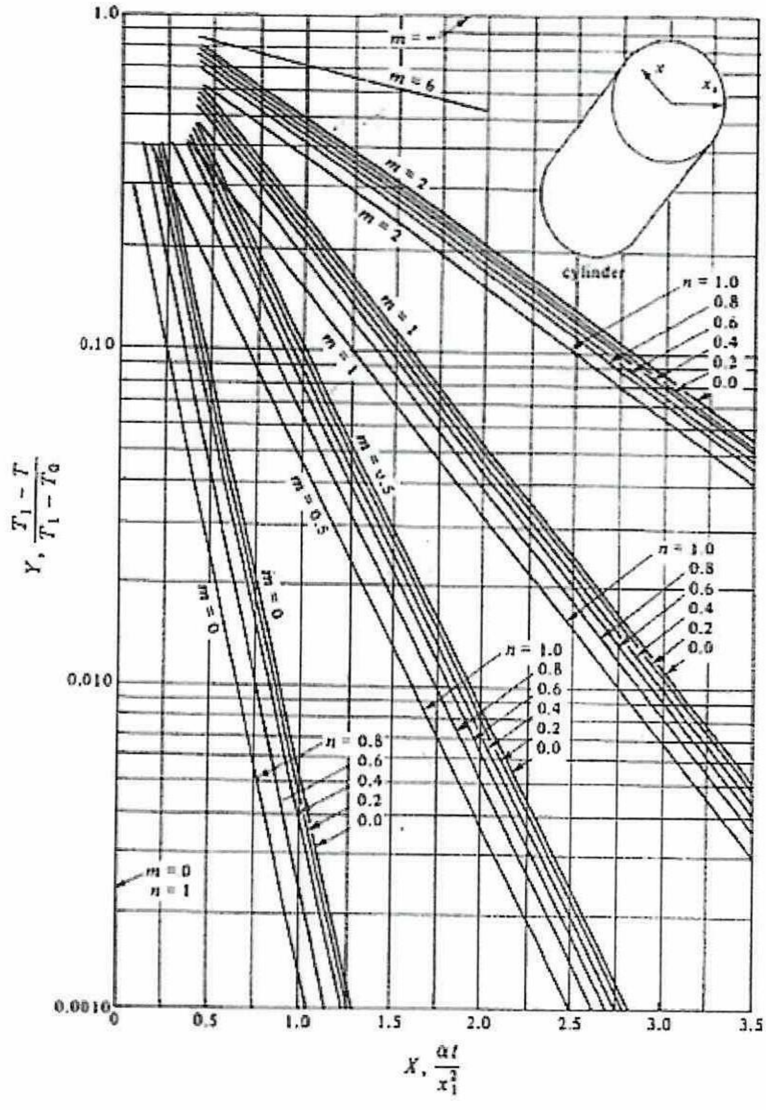
8.31451	$J\ K^{-1}\ mol^{-1}$
8.20578×10^{-2}	$L\ atm\ K^{-1}\ mol^{-1}$
8.31451×10^{-2}	$L\ bar\ K^{-1}\ mol^{-1}$
8.31451	$Pa\ m^{3}\ K^{-1}\ mol^{-1}$
62.364	$L\ Torr\ K^{-1}\ mol^{-1}$
1.98722	$cal\ K^{-1}\ mol^{-1}$

APPENDIX C



T_1 = Environment temperature
T_0 = Initial temperature
T = Temperature at 'x' length

Figure APPENDIX C.1 Unsteady-state heat conduction in a large flat plate



T_1 = Environment temperature
T_0 = Initial temperature
T = Temperature at 'x' length

Figure APPENDIX C.2 Unsteady-state heat conduction in a long cylinder

Table APPENDIX C.1 Relation between mass and heat transfer parameters for unsteady state diffusion

	Mass Transfer	
Heat Transfer	$K = c_L/c = 1.0$	$K = c_L/c \neq 1.0$
$Y, \dfrac{T_1 - T}{T_1 - T_0}$	$\dfrac{c_1 - c}{c_1 - c_0}$	$\dfrac{c_1/K - c}{c_1/K - c_0}$
$1 - Y, \dfrac{T - T_0}{T_1 - T_0}$	$\dfrac{c - c_0}{c_1 - c_0}$	$\dfrac{c - c_0}{c_1/K - c_0}$
$X, \dfrac{\alpha t}{x_1^2}$	$\dfrac{D_{AB}t}{x_1^2}$	$\dfrac{D_{AB}t}{x_1^2}$
$\dfrac{x}{2\sqrt{\alpha t}}$	$\dfrac{x}{2\sqrt{D_{AB}t}}$	$\dfrac{x}{2\sqrt{D_{AB}t}}$
$m, \dfrac{k}{hx_1}$	$\dfrac{D_{AB}}{k_c x_1}$	$\dfrac{D_{AB}}{Kk_c x_1}$
$\dfrac{h}{k}\sqrt{\alpha t}$	$\dfrac{k_c}{D_{AB}}\sqrt{D_{AB}t}$	$\dfrac{Kk_c}{D_{AB}}\sqrt{D_{AB}t}$
$n, \dfrac{x}{x_1}$	$\dfrac{x}{x_1}$	$\dfrac{x}{x_1}$

* x is the distance from the center of the slab, cylinder, or sphere; for a semiinfinite slab, x is the distance from the surface. c_0 is the original uniform concentration in the solid, c_1 the concentration in the fluid outside the slab, and c the concentration in the solid at position x and time t.

APPENDIX D

FORMULA

Q2) Mass Flux on spherical system

If S=m^3(STP)/atm.m^3 solid,

*Note: Unit pressure depend on question, it can be atm, bar, mmHg, Pa, etc.

$$c_A = \frac{Sp_A}{22.414}$$

If S= kmol /m^3.atm,

*Note: Unit pressure depend on question, it can be atm, bar, mmHg, Pa, etc.

$$c_A = Sp_A$$

c_A = concentration of the gas species in the solid at the interface (kmol.m^3)
p_A = partial pressure of the species in the gas on the gas side of the interface
S = solubility

$$N_{A1} = 4\pi r_1 r_2 D_{AB} \frac{C_{A1} - C_{A2}}{r_2 - r_1}$$

Q3) Flow in Pipe

$$N_{\mathrm{Re}} = \frac{D\upsilon\rho}{\mu}$$

$$N_{Sc} = \frac{\mu}{\rho D_{AB}}$$

$$\left(\frac{W}{D_{AB}\rho L}\right) = N_{\mathrm{Re}} N_{Sc} \frac{D}{L}\frac{\pi}{4}$$

$$\frac{c_A - c_{Ao}}{c_{Ai} - c_{Ao}} = 5.5\left(\frac{W}{D_{AB}\rho L}\right)^{-2/3}$$

Q4) Unsteady-State Mass Transfer

$$Y_{x,y,x} = (Y_x)(Y_y)(Y_Z) = \frac{{c_1}/{K} - c_{x,y,z}}{{c_1}/{K} - c_o}$$