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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	SEPARATION ENGINEERING TECHNOLOGY
COURSE CODE	:	BNQ 30104
PROGRAMME CODE	:	BNN
EXAMINATION DATE	:	DECEMBER 2019/JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

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Q1 (a) (i) A cooling tower system is common in industries and being used in various processes. State the function of the cooling tower and list **TWO (2)** purposes of the system in industry.

(3 marks)

(ii) Draw and label a complete cooling tower system.

(6 marks)

(iii) Describe in detail the cooling tower working mechanism and the problems that might occur for cooling tower system mentioned in **Q1(a)(ii).**

(8 marks)

(b) Provide **TWO (2)** comparisons (in table form) between the dilute and concentrated solutions in single evaporation calculation processes.

(2 marks)

(c) As an intern student, you are asked to obtain the antioxidant from herb called *Andographis Paniculata* (Green chiretta) in order to be applied in homemade bread. The bread will later compared with the bread incoporated with commercial antioxidant, butylated hydroxyanisole (BHA). Propose the process and the important steps to obtain the antioxidant needed.

(6 marks)

Q2 A single-effect evaporator is concentrating a feed of organic colloids from 5 to 50 wt%. The solution has a negligible boiling-point elevation. The heat capacity of the feed is c_p = 4.06 kJ/kg.K and the feed enters at 15.6 °C. Saturated steam at 101.32 kPa is available for heating, and the pressure in the vapor space of the evaporator is 15.3 kPa. A total of 4536 kg/h of water is to be evaporated. The overall heat-transfer coefficient is 1988 W/m^2.K.

(a) Sketch the process flow diagram and label the process variables.

(5 marks)

(b) Based on the total mass balance, determine the unknown value that flow in and out of the evaporator stream.

(5 marks)

(c) Calculate the steam consumption (kg/h), surface area (m^2) and the steam economy in kg vaporized/kg steam. Refer **Table Q2(i)** and **Q2(ii)** for properties of saturated steam and water.

(15 marks)

Q3 Fresh Cod fish livers containing 25.7 wt% oil are to be extracted with pure isopropanol to remove 95% of the oil in a countercurrent multistage leaching process. The feed rate is 1000 kg of fresh livers per hour. The final exit overflow solution is to contain 70 wt% oil. The retentaion of solution by the inert solids (oil-free liver) of the liver varies as shown in **Table Q3**.

Table Q3: The retention of solution by the inert solids (oil-free liver) of the liver

N (kg inert solid/kg solution retained)	y_A (kg oil/kg solution)
4.88	0
3.50	0.2
2.47	0.4
1.67	0.6
1.39	0.81

(a) Sketch the process flow diagram and label the process variables.

(5 marks)

(b) Calculate the amounts and compositions of the exit streams.

(10 marks)

(c) Plot the graph needed in order to identify the number of stages required for this process.

(10 marks)

Q4 A tray tower is to be designed to absorb SO_2 from an air stream by using pure water. The entering gas contains 20 mol% SO_2 and leaving the absorber with 2 mol%. The entering pure water flow rate is 6000 kg H_2O/h and the inert air flow is 150 kg air/h. Use the equilibrium data as shown in the following **Table Q4**. (Mw: air =29 kg/mol, water =18 kg/mol).

Table Q4: Table of Equilibrium Data for SO_2 – Water System

Equilibrium Data for SO_2-Water System	
x_A	y_A
0	0
0.0000562	0.000658
0.0001403	0.00158
0.00028	0.00421
0.000422	0.00763
0.000564	0.01120
0.000842	0.01855
0.001403	0.0342
0.001965	0.0513
0.00279	0.0775
0.0042	0.121
0.00698	0.212

(a) Sketch the process flow diagram and label the process variables.

(5 marks)

(b) Calculate the outlet composition of the gas.

(10 marks)

(c) Plot the operating line based on the data given above.

(5 marks)

(d) Determine the theoretical and actual trays for this system if the tray efficiency is 25%

(5 marks)

- END OF QUESTION –

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2019/2020
COURSE NAME: SEPARATION ENGINEERING TECHNOLOGY

PROGRAMME CODE: BNN
COURSE CODE: BNQ 30104

Unit Conversion

R value

R= 8.31451 J K^{-1} mol^{-1} = 8.20578x10^{-2} L atm K^{-1} mol^{-1} = 8.31451x10^{-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}

Liquid water properties at 0°C (273.2 K)

Density (ρ) = 999.6 kg/m^3
Heat capacity (c_p) = 4.229 kJ/kg. K

Pressure

1 bar = 1 x 10^5 Pa = 1 x 10^5 N/m^2
1 atm = 760 mm Hg = 1.01325 x 10^5 Pa = 1.01325 x 10^2 kPa= 1.01325 bar
1 mm Hg = 1.333224x10^2 N/m^2 = 0.1333224 kPa

Temperature

K = °C+273.15
°F= 32 + 1.8(°C)
°R= °F+459.67
100 °C = 212 °F + 373.15 K = 671.67 °R
0 °C= 32 °F = 273.15 K = 491.67 °R

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2019/2020
COURSE NAME: SEPARATION ENGINEERING TECHNOLOGY

PROGRAMME CODE: BNN
COURSE CODE: BNQ 30104

Formula

Evaporation

Total Material balance: $F = L + V$

Solute/Solid balance: $F(x_F) = L(x_L)$

Energy balance: $Fh_F + S(H_S - h_S) = Lh_L + VH_V$

Heat Transfer equation: $q = S\lambda = UA\Delta T = UA(T_S - T_1)$

Where,

$S(H_S - h_S) = S\lambda$ $\quad h = c_P(T - T_{ref.})\,(T_{ref.} = T_1)$ $\quad H_V = \text{latent heat at } T_1 (T_{ref.} = T_1)$

$T_1 = T_{sat.\text{ at }P1} + BPR$ $\quad H_V = H_{sat.\text{ at }P1} + 1.884(BPR)$

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2019/2020
COURSE NAME: SEPARATION ENGINEERING TECHNOLOGY

PROGRAMME CODE: BNN
COURSE CODE: BNQ 30104

COUNTERCURRENT MULTISTAGE LEACHING

Concentration of inert solid (B) in *solution* of underflow, N:

$$N = \frac{\text{kg B}}{\text{kg A} + \text{kg C}}$$

Weight fraction of solute (A) in overflow V (overflow liquid), x_A: $x_A = \frac{\text{kg A}}{\text{kg A} + \text{kg C}}$

Weight fraction of solute (A) in underflow's solution L (liquid in slurry), y_A: $y_A = \frac{\text{kg A}}{\text{kg A} + \text{kg C}}$

Total material balance:

$$L_0 + V_{N+1} = L_N + V_1 = M$$

Balance on A:

$$L_0 y_{A0} + V_{N+1} x_{AN+1} = L_N y_{AN} + V_1 x_{A1} = M x_{AM}$$

Absorption

Balance on A:

$$L'\left(\frac{x_{A0}}{1-x_{A0}}\right) + V'\left(\frac{y_{AN+1}}{1-y_{AN+1}}\right) = L'\left(\frac{x_{AN}}{1-x_{AN}}\right) + V'\left(\frac{y_{A1}}{1-y_{A1}}\right)$$

FINAL EXAMINATION

SEMESTER/SESSION: SEM I 2019/2020 PROGRAMME CODE: BNN
COURSE NAME: SEPARATION ENGINEERING TECHNOLOGY COURSE CODE: BNQ 30104

Figure and Table

Table Q2(i): Properties of saturated steam and water

Temperature (°C)	Vapor Pressure (kPa)	Specific Volume (m^3/kg)		Enthalpy (kJ/kg)		Entropy (kJ/kg · K)	
		Liquid	Sat'd Vapor	Liquid	Sat'd Vapor	Liquid	Sat'd Vapor
0.01	0.6113	0.0010002	206.136	0.00	2501.4	0.0000	9.1562
3	0.7577	0.0010001	168.132	12.57	2506.9	0.0457	9.0773
6	0.9349	0.0010001	137.734	25.20	2512.4	0.0912	9.0003
9	1.1477	0.0010003	113.386	37.80	2517.9	0.1362	8.9253
12	1.4022	0.0010005	93.784	50.41	2523.4	0.1806	8.8524
15	1.7051	0.0010009	77.926	62.99	2528.9	0.2245	8.7814
18	2.0640	0.0010014	65.038	75.58	2534.4	0.2679	8.7123
21	2.487	0.0010020	54.514	88.14	2539.9	0.3109	8.6450
24	2.985	0.0010027	45.883	100.70	2545.4	0.3534	8.5794
25	3.169	0.0010029	43.360	104.89	2547.2	0.3674	8.5580
27	3.567	0.0010035	38.774	113.25	2550.8	0.3954	8.5156
30	4.246	0.0010043	32.894	125.79	2556.3	0.4369	8.4533
33	5.034	0.0010053	28.011	138.33	2561.7	0.4781	8.3927
36	5.947	0.0010063	23.940	150.86	2567.1	0.5188	8.3336
40	7.384	0.0010078	19.523	167.57	2574.3	0.5725	8.2570
45	9.593	0.0010099	15.258	188.45	2583.2	0.6387	8.1648
50	12.349	0.0010121	12.032	209.33	2592.1	0.7038	8.0763
55	15.758	0.0010146	9.568	230.23	2600.9	0.7679	7.9913
60	19.940	0.0010172	7.671	251.13	2609.6	0.8312	7.9096
65	25.03	0.0010199	6.197	272.06	2618.3	0.8935	7.8310
70	31.19	0.0010228	5.042	292.98	2626.8	0.9549	7.7553
75	38.58	0.0010259	4.131	313.93	2635.3	1.0155	7.6824
80	47.39	0.0010291	3.407	334.91	2643.7	1.0753	7.6122
85	57.83	0.0010325	2.828	355.90	2651.9	1.1343	7.5445
90	70.14	0.0010360	2.361	376.92	2660.1	1.1925	7.4791
95	84.55	0.0010397	1.9819	397.96	2668.1	1.2500	7.4159
100	101.35	0.0010435	1.6729	419.04	2676.1	1.3069	7.3549

FINAL EXAMINATION

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COURSE NAME: SEPARATION ENGINEERING TECHNOLOGY

PROGRAMME CODE: BNN
COURSE CODE: BNQ 30104

Table Q2(ii): Properties of saturated steam and water (continued)

A.2-9 SI Units, *Continued*

Temperature (°C)	Vapor Pressure (kPa)	Specific Volume (m^3/kg)		Enthalpy (kJ/kg)		Entropy (kJ/kg · K)	
		Liquid	Sat'd Vapor	Liquid	Sat'd Vapor	Liquid	Sat'd Vapor
105	120.82	0.0010475	1.4194	440.15	2683.8	1.3630	7.2958
110	143.27	0.0010516	1.2102	461.30	2691.5	1.4185	7.2387
115	169.06	0.0010559	1.0366	482.48	2699.0	1.4734	7.1833
120	198.53	0.0010603	0.8919	503.71	2706.3	1.5276	7.1296
125	232.1	0.0010649	0.7706	524.99	2713.5	1.5813	7.0775
130	270.1	0.0010697	0.6685	546.31	2720.5	1.6344	7.0269
135	313.0	0.0010746	0.5822	567.69	2727.3	1.6870	6.9777
140	316.3	0.0010797	0.5089	589.13	2733.9	1.7391	6.9299
145	415.4	0.0010850	0.4463	610.63	2740.3	1.7907	6.8833
150	475.8	0.0010905	0.3928	632.20	2746.5	1.8418	6.8379
155	543.1	0.0010961	0.3468	653.84	2752.4	1.8925	6.7935
160	617.8	0.0011020	0.3071	675.55	2758.1	1.9427	6.7502
165	700.5	0.0011080	0.2727	697.34	2763.5	1.9925	6.7078
170	791.7	0.0011143	0.2428	719.21	2768.7	2.0419	6.6663
175	892.0	0.0011207	0.2168	741.17	2773.6	2.0909	6.6256
180	1002.1	0.0011274	0.19405	763.22	2778.2	2.1396	6.5857
190	1254.4	0.0011414	0.15654	807.62	2786.4	2.2359	6.5079
200	1553.8	0.0011565	0.12736	852.45	2793.2	2.3309	6.4323
225	2548	0.0011992	0.07849	966.78	2803.3	2.5639	6.2503
250	3973	0.0012512	0.05013	1085.36	2801.5	2.7927	6.0730
275	5942	0.0013168	0.03279	1210.07	2785.0	3.0208	5.8938
300	8581	0.0010436	0.02167	1344.0	2749.0	3.2534	5.7045

Source: Abridged from J. H. Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore, *Steam Tables—Metric Units*, New New York: John Wiley & Sons, Inc., 1969. Reprinted by permission of John Wiley & Sons, Inc.