UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	UNIT OPERATIONS IN FOOD PROCESSING
COURSE CODE	:	BWD 21903
PROGRAMME CODE	:	BWD
EXAMINATION DATE	:	JULY/AUGUST 2023
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 **EIGHT (8)** PAGES

Q1 For dried products such as instant coffee, humidity ratio is one of the critical parameters that need to be measured during processing.

(a) Define the humidity ratio.

(2 marks)

(b) The instant coffee is dried at a dry bulb temperature of 50°C and a wet bulb temperature of 40°C. Calculate the humidity ratio and relative humidity of the air.

(10 marks)

(c) Wet bulb temperature is the adiabatic saturation temperature. Describe how to measure wet bulb temperature.

(3 marks)

(d) In an effort to conserve energy, a food dryer is being modified to reuse part of the exhaust air along with ambient air. The exhaust airflow of 10 m^3/s at 70°C and 30% relative humidity is mixed with 20 m^3/s of ambient air at 30°C and 60% relative humidity. Using the psychrometric chart, determine the dry bulb temperature and humidity ratio of the mixed air.

(10 marks)

Q2 Dehydration of foodstuffs involves the removal of water to increase the storage stability of perishable food items. For many people, dehydrating food at home is a convenient way to preserve food.

(a) Discuss **TWO (2)** factors that affect drying rate.

(4 marks)

(b) Discuss all of the drying stages observed on a drying curve.

(5 marks)

(c) Estimate the time necessary to dry an apple from 75% to 20% moisture content (on wet basis) under constant external conditions. Under the process conditions, a falling rate regime is known to prevail during drying. A linear relationship between drying rate and residual moisture is assumed. When the moisture content of the apples is 75%, the initial drying rate of the apples becomes 0.5 kg water removed per kg of dry air per hour. The moisture content of the apple at equilibrium with the drying air is 8% (wet basis).

(10 marks)

(d) Discuss **THREE (3)** different food dehydration systems.

(6 marks)

Q3 Freezing of food is a process of lowering the temperature of food to a range between -18 and -60 °C.

(a) List **FIVE (5)** reasons for freezing food.

(5 marks)

(b) Perishable food products such as beef, have a higher water activity. Predict what would occur to the beef if it was kept in a freezer for a week.

(5 marks)

(c) Analyze the frequent types of deterioration in frozen beef.

(15 marks)

Q4 (a) Membrane filtration is a process of separating food components by using semipermeable membranes, based on the molecular size and molecular weight of the components.

(i) Give **TWO (2)** examples of substances that can be removed by nanofiltration and microfiltration.

(5 marks)

(ii) Compare the operations of reverse osmosis (RO) and ultrafiltration (UF) of water containing fat, protein, lactose and minerals.

(10 marks)

(b) Initially, the butterfat content of raw milk is roughly 4% (by weight). If the milk is left at room temperature for 24 hours, a significant percentage of cream would naturally float over the skimmed milk and can be removed. The fat content of the skimmed milk should be between 0.1% and 0.3% prior to consumption.

(i) Select an effective separation method to reduce the operating time.

(2 marks)

(ii) Based on your answer in **Q4 (b)(i)**, explain the operation principles of the separation process with the aid of an illustration.

(8 marks)

- END OF QUESTIONS -

APPENDIX A

Molecular weight of standard dry air	=	287.055 m^3Pa/kg.K
Molecular weight of water	=	461.52 m^3Pa/kg.K
Specific heat of water vapor	=	1.88 kJ/kg.K
Specific heat of dry air	=	1.005 kJ/kg dry air K
ρ_B is the barometric pressure (kPa)	=	101.325 kPa

Enthalpy, $H_a = 1.005\ (Ta - T0)$

Enthalpy, $H_w = 2501.4 + 1.88(Ta - T0)$

$W = \left(\frac{18.01534}{28.9645}\right)\frac{Xw}{Xa} = 0.622\ \left(\frac{Xw}{Xa}\right)$

$$\emptyset = \frac{x_w}{x_{ws}} \times 100$$

$$\emptyset = \frac{p_w}{p_{ws}} \times 100$$

$$c_s = 1.005 + 1.88W$$

$$V_m' = (0.082T_a + 22.4)\left(\frac{1}{29} + \frac{W}{18}\right)$$

$$p = p_{wb} - \frac{(p_B - p_{wb})(T_a - T_w)}{1555.56 - 0.722T_w}$$

$$t = \frac{X1 - X2}{\Phi 0}$$

$$t = \frac{Xc - Xe}{\Phi 0} . \ln\left(\frac{X1 - Xe}{X2 - Xe}\right)$$

$$= \frac{X1 - X2}{\Phi 0} + \frac{Xc - Xe}{\Phi 0} . \ln\left(\frac{Xc - Xe}{X2 - Xe}\right)$$

APPENDIX B

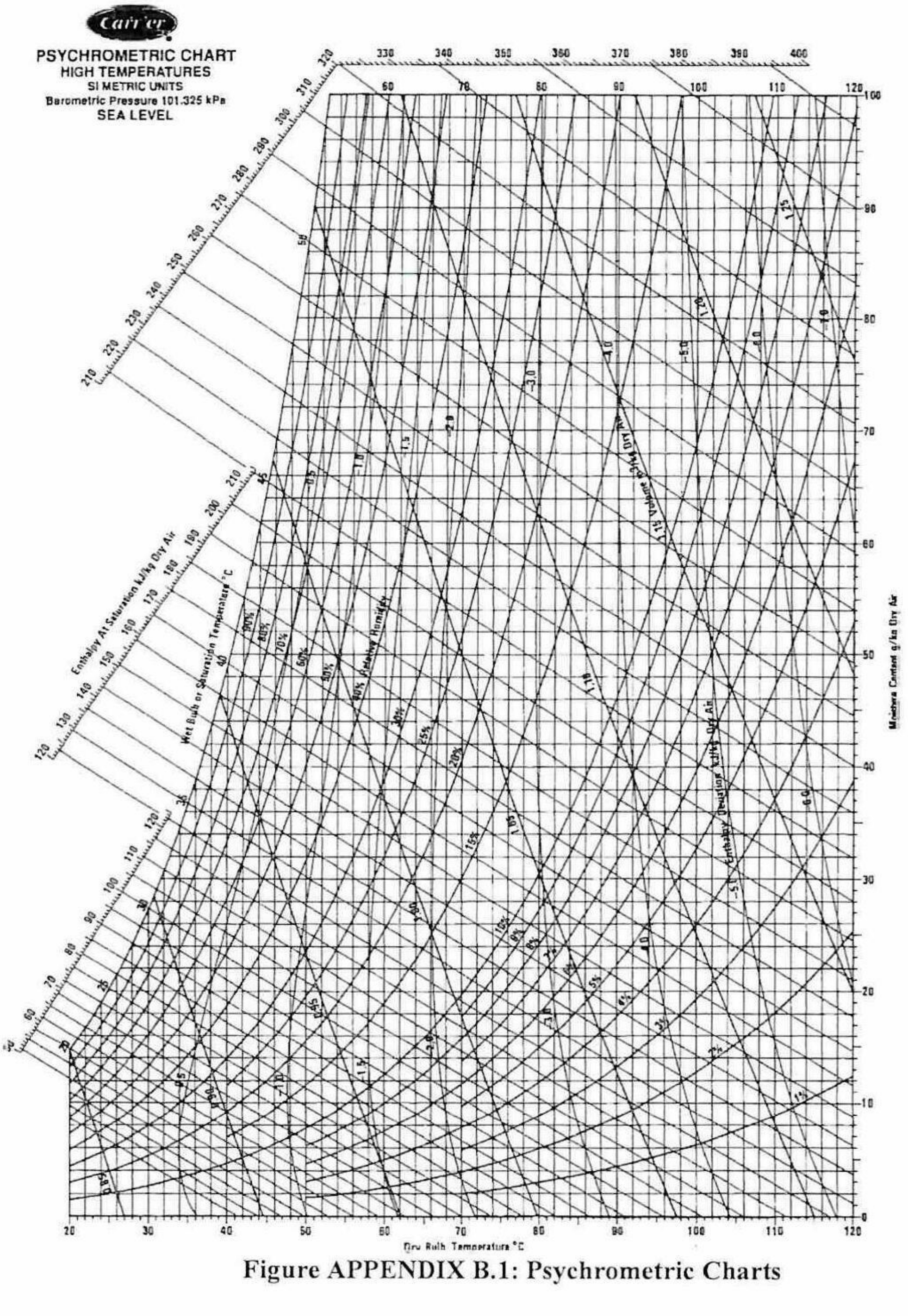

Figure APPENDIX B.1: Psychrometric Charts

APPENDIX C

Table APPENDIX C.1: Physical Properties of Water

Table A.4.1 (*Continued*)

Temperature T (°C)	Temperature T (K)	Density ρ (kg/m³)	Coefficient of volumetric thermal expansion β (×10⁻⁴ K⁻¹)	Specific heat c_p (kJ/[kg °C])	Thermal conductivity k (W/[m °C])	Thermal diffusivity α (×10⁻⁶ m²/s)	Absolute viscosity μ (×10⁻⁶ Pa s)	Kinematic viscosity ν (×10⁻⁶ m²/s)	Prandtl number N_{Pr}
180	453.15	886.6	12.1	4.396	0.673	0.172	152.003	0.173	1.01
190	463.15	876.0	12.8	4.480	0.670	0.171	145.138	0.166	0.97
200	473.15	862.8	13.5	4.501	0.665	0.170	139.254	0.160	0.95
210	483.15	852.8	14.3	4.560	0.655	0.168	131.409	0.154	0.92
220	493.15	837.0	15.2	4.605	0.652	0.167	124.544	0.149	0.90
230	503.15	827.3	16.2	4.690	0.637	0.164	119.641	0.145	0.88
240	513.15	809.0	17.2	4.731	0.634	0.162	113.757	0.141	0.86
250	523.15	799.2	18.6	4.857	0.618	0.160	109.834	0.137	0.86

Source: Adapted from Raznjevic (1978)

Table APPENDIX C.2: Properties of Saturated Steam

Table A.4.2 Properties of Saturated Steam

Temperature (°C)	Vapor pressure (kPa)	Specific volume (m³/kg) Liquid	Specific volume (m³/kg) Saturated vapor	Enthalpy (kJ/kg) Liquid (H_c)	Enthalpy (kJ/kg) Saturated vapor (H_v)	Entropy (kJ/[kg °C]) Liquid	Entropy (kJ/[kg °C]) Saturated 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
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

Table APPENDIX C.3: Properties of Saturated Steam (Cont.)

Table A.4.2 *(Continued)*

Temperature (°C)	Vapor pressure (kPa)	Specific volume (m^3/kg) Liquid	Specific volume (m^3/kg) Saturated vapor	Enthalpy (kJ/kg) Liquid (H_c)	Enthalpy (kJ/kg) Saturated vapor (H_v)	Entropy (kJ/[kg °C]) Liquid	Entropy (kJ/[kg °C]) Saturated vapor
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
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	361.3	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 Keenan et al. (1969).

Table APPENDIX C.4: Properties of Superheated Steam

Table A.4.3 Properties of Superheated Steam

Absolute pressure (kPa, with sat. temperature, °C)[a]		Temperature (°C)							
		100	150	200	250	300	360	420	500
10	V	17.196	19.512	21.825	24.136	26.445	29.216	31.986	35.679
(45.81)	H	2687.5	2783.0	2879.5	2977.3	3076.5	3197.6	3320.9	3489.1
	s	8.4479	8.6882	8.9038	9.1002	9.2813	9.4821	9.6682	9.8978
50	V	3.418	3.889	4.356	4.820	5.284	5.839	6.394	7.134
(81.33)	H	2682.5	2780.1	2877.7	2976.0	3075.5	3196.8	3320.4	3488.7
	s	7.6947	7.9401	8.1580	8.3556	8.5373	8.7385	8.9249	9.1546
75	V	2.270	2.587	2.900	3.211	3.520	3.891	4.262	4.755
(91.78)	H	2679.4	2778.2	2876.5	2975.2	3074.9	3196.4	3320.0	3488.4
	s	7.5009	7.7496	7.9690	8.1673	8.3493	8.5508	8.7374	8.9672
100	V	1.6958	1.9364	2.172	2.406	2.639	2.917	3.195	3.565
(99.63)	H	2676.2	2776.4	2875.3	2974.3	3074.3	3195.9	3319.6	3488.1
	s	7.3614	7.6134	7.8343	8.0333	8.2158	8.4175	8.6042	8.8342
150	V		1.2853	1.4443	1.6012	1.7570	1.9432	2.129	2.376
(111.37)	H		2772.6	2872.9	2972.7	3073.1	3195.0	3318.9	3487.6
	s		7.4193	7.6433	7.8438	8.0720	8.2293	8.4163	8.6466
400	V		0.4708	0.5342	0.5951	0.6458	0.7257	0.7960	0.8893
(143.63)	H		2752.8	2860.5	2964.2	3066.8	3190.3	3315.3	3484.9
	s		6.9299	7.1706	7.3789	7.5662	7.7712	7.9598	8.1913
700	V			0.2999	0.3363	0.3714	0.4126	0.4533	0.5070
(164.97)	H			2844.8	2953.6	3059.1	3184.7	3310.9	3481.7
	s			6.8865	7.1053	7.2979	7.5063	7.6968	7.9299
1000	V			0.2060	0.2327	0.2579	0.2873	0.3162	0.3541
(179.91)	H			2827.9	2942.6	3051.2	3178.9	3306.5	3478.5
	s			6.6940	6.9247	7.1229	7.3349	7.5275	7.7622
1500	V			0.13248	0.15195	0.16966	0.18988	0.2095	0.2352
(198.32)	H			2796.8	2923.3	3037.6	3.1692	3299.1	3473.1
	s			6.4546	6.7090	6.9179	7.1363	7.3323	7.5698
2000	V				0.11144	0.12547	0.14113	0.15616	0.17568
(212.42)	H				2902.5	3023.5	3159.3	3291.6	3467.6
	s				6.5453	6.7664	6.9917	7.1915	7.4317
2500	V				0.08700	0.09890	0.11186	0.12414	0.13998
(223.99)	H				2880.1	3008.8	3149.1	3284.0	3462.1
	s				6.4085	6.6438	6.8767	7.0803	7.3234
3000	V				0.07058	0.08114	0.09233	0.10279	0.11619
(233.90)	H				2855.8	2993.5	3138.7	3276.3	3456.5
	s				6.2872	6.5390	6.7801	6.9878	7.2338

Source: Abridged from Keenan et al. (1969). Copyright © 1969 by John Wiley and Sons. Reprinted by permission of John Wiley and Sons, Inc.

[a] V, specific volume, m^3/kg; H, enthalpy, kJ/kg; s, entropy, kJ/kg K.