THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

SECOND SEMESTER EXAMINATIONS – 2022

FOOD TECHNOLOGY – FOURTH YEAR DEGREE

FT 423 UNIT OPERATIONS II

TUESDAY 1ST NOVEMBER – 8:20 AM

TIME ALLOWED: 3 HOURS

INFORMATION FOR CANDIDATES:

1. You have 10 minutes to read the paper. You must not begin writing in the answer book during this time.
2. **ANSWER ALL QUESTIONS**
3. All answers must be written in the answer books provided.
4. Write your name and number clearly on the front page. **Do it now.**
5. Calculators are permitted in the examination room. Notes and textbooks, laptops and mobile phones are not allowed.
6. Show all workings and calculations in the answer book.
7. **ALWAYS** start a new question on a new page.
8. Your "Attendance Slip" is in your answer booklet.

MARKING SCHEME

Question 1	[19 marks]
Question 2	[15½ marks]
Question 3	[18½ marks]
Question 4	[13 marks]
Question 5	[13½ marks]
Question 6	[20½ marks]

ANSWER ALL QUESTIONS.

1. (a) Compare and contrast open and closed loop control systems in process control. [5 marks]

(b) Discuss the terms "dynamic variable" and "regulation" using a production routine where process fluid temperature and flow rate are monitored continuously. [4 marks]

(c) Explain the objectives that the manufacturing industry attain when using process control? [3 marks]

(d) Discuss the following parts of a measuring system:

(i) Primary transducer. [2 marks]
(ii) Signal processing. [2 marks]

(e) When choosing a temperature measuring instrument for an application, what will be your important considerations? [3 marks]

(Total =19 marks)

2. (a) Versatility is one of the reasons why extrusion has gained popularity in the manufacturing industry. Explain all the characteristics of extrusion that gives it this quality. [2½ marks]

(b) Describe how twin-screw extruders are classified into:

(i) Intermeshing and non-intermeshing screws. [2 marks]
(ii) Conjugated and non-conjugated screws. [2 marks]
(iii) Co-rotating and counter-rotating. [1 mark]

(c) Process variables have some effect on the extrudate in extrusion. Discuss these effects under the following headings:

(i) Temperature. [2 marks]
(ii) Screw speed. [2 marks]
(iii) Die diameter. [2 marks]
(iv) Feed rate. [2 marks]

(Total = 15½ marks)

3. (a) Explain the techniques by which filtration can be achieved. [5½ marks]

(b) A sugar slurry is to be filtered at a constant total pressure of 120 kN.m^{-2} through a filter medium whose diameter measures 0.32 m. If the solids collected on the filter medium are at a ratio of 25 kg for every cubic metre (m^3) of filtrate (viscosity = 8.92x10^{-4} N.s.m^{-2}) collected, determine the total time required to collect 5.5 x 10^6 mm^3 of filtrate? Determine the specific cake resistance and the filter medium resistance if the initial readings of the run are:

Filtrate (mm^3)	Time (s)
0.00	0.00
2 x 10^5	13
4 x 10^5	28
6 x 10^5	51
8 x 10^5	80
1 x 10^6	113

[13 marks]

(Total = 18½ marks)

4. (a) If two immiscible liquids are placed in a bowl rotating about a central axis, describe their behaviour. Use an illustration to demonstrate your description. [4 marks]

(b) A disc bowl centrifuge with its characteristics listed below was used to separate a solid–liquid suspension to give a cut-point diameter of 3.0 µm. The thickness of the liquid layer in the bowl was 2500 µm and the density of the liquid and solids phases were 1006 kg.m^{-3}, and 1300 kg.m^{-3} respectively. The viscosity of the liquid was found to be 9.0 x 10^{-4} Pa.s.

Bowl Characteristics

Bowl depth	=	32 cm.
Number of discs	=	42.
Inner diameter of discs	=	36 mm.
Outer diameter of discs	=	50 mm.
Conical half angle of discs	=	52°.
Bowl speed	=	8000 rpm.

(i) Calculate the velocity of the particles. [3 marks]

(ii) Calculate the through-put of the centrifuge. [6 marks]

(Total = 13 marks)

5. (a) Answer the following questions with respect to irradiation:

(i) Wavelength range for γ – rays and X – rays. [1 mark]
(ii) Frequency range for γ – rays and X – rays. [1 mark]
(iii) Equivalent of 1rad in $J.kg^{-1}$. [1 mark]
(iv) Factors influencing irradiation dose administered. [1 mark]
(v) The radiation dose capable of raising the product temperature by 1°C. [1 mark]
(vi) The equivalent of TWO half-lives. [1 mark]

(b) Discuss irradiation of foods in the presence of oxygen.
In your answer, state how this is avoided in irradiating fatty foods. [3½ marks]

(c) Discuss disinfection by irradiation. [4 marks]

(Total = 13½ marks)

6. (a) Liquid boiling point, overall heat transfer coefficient and liquid feed properties affect heat transfer in evaporation. Discuss the liquid boiling point under the following headings:

(i) External pressure. [4 marks]
(ii) Dissolved solutes. [4 marks]

(c) Pineapple juice at the rate of 15,000 $kg.h^{-1}$ is concentrated in a single effect evaporator from 18% to 25% total solids. The juice enters the evaporator at its boiling point of 50 °C and saturated steam at 100 °C is used as the heating medium for this duty. The condensate exits at 100°C and the specific heat capacity of the juice is $3.7 kJ.kg^{-1}.°C^{-1}$ and $3.6\ kJ.kg^{-1}.°C^{-1}$ at the inlet and the outlet of the evaporator respectively. The overall heat transfer coefficient is $1500\ W.m^{-2}.°C^{-1}$. Calculate the:

(i) Product flow rate. [2½ marks]
(ii) Evaporation rate. [2½ marks]
(iii) *Steam consumption.* [2½ marks]
(iv) Steam economy. [2½ marks]
(v) Required heat transfer area. [2½ marks]

(Total = 20½ marks)

USEFULL DATA

$F = P + V$

$F x_F = P x_P + V x_V$

$$Penetration\ (cm) = \frac{0.524\,E - 0.1337}{\rho}$$

$F(1 - x_F) = P(1 - x_P) + V$

$Q = S L_S = U.A.\Delta\theta$

$\Delta\theta = (\theta_s - \theta_e)$

$S L_S = F C P_F\,(\theta_e - \theta_f) + V L_V$

$Q = S L_S = U.A.(\theta s - \theta e) = F C P_F\,(\theta s - \theta e) + V L_V$

$A_1 = A_2 = A_3,\ U_1.\Delta\theta_1 = U_2.\Delta\theta_2 = U_3.\Delta\theta_3$

$Q_1 = U_1.A.\Delta\theta_1$ where $\Delta\theta_1 = (\theta_s - \theta_1)$
$Q_2 = U_2.A.\Delta\theta_2$ where $\Delta\theta_2 = (\theta_1 - \theta_2)$
$Q_3 = U_3.A.\Delta\theta_3$ where $\Delta\theta_3 = (\theta_2 - \theta_3)$

$$\frac{1}{U} = \frac{1}{h_1} + \frac{x_w}{k_w} + \frac{1}{h_2}$$

$$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

$A = \pi d L$ (Cylinder Wall) $A = \frac{\pi d^2}{4}$ (Cylinder end)

$-\Delta P = -\Delta P_c + -\Delta P_m$	$(-\Delta P_c)^{1-s} = \frac{\propto_o\,\mu w}{A^2}\left[\frac{V}{t}\right] t = K"t$
$-\Delta P_c = \frac{\propto \mu w V}{A^2}\left[\frac{dV}{dt}\right]$	$(-\Delta P_c)^{1-s} = \frac{\propto_o\,\mu w}{A^2}[\frac{V}{t}]^2$
$\propto = \frac{k(1-x)S_o^2}{x^3 \rho^s}$	$\omega = \frac{\pi N}{30}$
$-\Delta P_m = \frac{R_m \mu}{A}\left[\frac{dV}{dt}\right]$	$V_t = \frac{\omega^2(\rho_s - \rho_l)D_{pc}^2 R}{18\mu}$

$\frac{dV}{dt} = \frac{A(-\Delta P)}{\mu\left[\frac{\propto wV}{A} + R_m\right]}$	$q = 2.V_g.\Sigma$
$t = \frac{\mu}{(-\Delta P)}\left[\frac{\propto w}{2}[\frac{V}{A}]^2 + R_m[\frac{V}{A}]\right]$	$\Sigma = \frac{\pi\omega^2 b(3R_2^2 + R_1^2)}{2g}$
$\frac{dt}{dV}$ =KV + B	$\Sigma = \frac{2\pi\omega^2(S-1)(R_x^3 - R_y^3)}{3g\tan\Omega}$
$K = \frac{\mu \propto w}{A^2(-\Delta P)}$	$(-\Delta P_c)^{1-s} = \frac{\propto_o \mu wV}{A^2}\left[\frac{V}{t}\right]$
$B = \frac{\mu R_m}{A(-\Delta P)}$	$-\Delta P = \left[\frac{\mu \propto w}{A^2}\left[\frac{V}{t}\right]\right]V + \left[\frac{\mu R_m}{A}\left[\frac{V}{t}\right]\right]$
$\propto = \propto_o (-\Delta P_c)^s$	$V_g = \frac{g(\rho_s - \rho_l)D_{pc}^2}{18\mu}$

Vertical axis	Horizontal axis	Slope	Y-Intercept
dt/dv	V	K	B
log$\propto$	log(-ΔP_c)	s	
-ΔP	V or t	K'	B'
log t	log (-ΔP_c)	1-s	

Absolute pressure (kPa, kN/m²)	Temperature (°C)	Specific Volume (m³/kg)	Density - ρ - (kg/m³)	Specific Enthalpy of Liquid - h_f - (kJ/kg)	Specific Enthalpy of Evaporation - h_{fg} - (kJ/kg)	Specific Enthalpy of Steam - h_g - (kJ/kg)	Specific Entropy of Steam - s - (kJ/kgK)
0.8	3.8	160	0.00626	15.8	2493	2509	9.058
2.0	17.5	67.0	0.0149	73.5	2460	2534	8.725
5.0	32.9	28.2	0.0354	137.8	2424	2562	8.396
10.0	45.8	14.7	0.0682	191.8	2393	2585	8.151
20.0	60.1	7.65	0.131	251.5	2358	2610	7.909
28	67.5	5.58	0.179	282.7	2340	2623	7.793
35	72.7	4.53	0.221	304.3	2327	2632	7.717
45	78.7	3.58	0.279	329.6	2312	2642	7.631
55	83.7	2.96	0.338	350.6	2299	2650	7.562
65	88.0	2.53	0.395	368.6	2288	2657	7.506
75	91.8	2.22	0.450	384.5	2279	2663	7.457
85	95.2	1.97	0.507	398.6	2270	2668	7.415
95	98.2	1.78	0.563	411.5	2262	2673	7.377
100	99.6	1.69	0.590	417.5	2258	2675	7.360
101.33[1]	100	1.67	0.598	419.1	2257	2676	7.355
110	102.3	1.55	0.646	428.8	2251	2680	7.328
130	107.1	1.33	0.755	449.2	2238	2687	7.271
150	111.4	1.16	0.863	467.1	2226	2693	7.223
170	115.2	1.03	0.970	483.2	2216	2699	7.181
190	118.6	0.929	1.08	497.8	2206	2704	7.144
220	123.3	0.810	1.23	517.6	2193	2711	7.095
260	128.7	0.693	1.44	540.9	2177	2718	7.039
280	131.2	0.646	1.55	551.4	2170	2722	7.014
320	135.8	0.570	1.75	570.9	2157	2728	6.969
360	139.9	0.510	1.96	588.5	2144	2733	6.930
400	143.6	0.462	2.16	604.7	2133	2738	6.894
440	147.1	0.423	2.36	619.6	2122	2742	6.862
480	150.3	0.389	2.57	633.5	2112	2746	6.833
500	151.8	0.375	2.67	640.1	2107	2748	6.819
550	155.5	0.342	2.92	655.8	2096	2752	6.787
600	158.8	0.315	3.175	670.4	2085	2756	6.758
650	162.0	0.292	3.425	684.1	2075	2759	6.730
700	165.0	0.273	3.66	697.1	2065	2762	6.705
750	167.8	0.255	3.915	709.3	2056	2765	6.682
800	170.4	0.240	4.16	720.9	2047	2768	6.660
850	172.9	0.229	4.41	732.0	2038	2770	6.639