THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

FIRST SEMESTER EXAMINATION – 2021

FOOD TECHNOLOGY – 3RD YEAR DEGREE

FT 311 FOOD ENGINEERING II

TUESDAY 8TH JUNE 2021 – 12:50 P.M.

TIME ALLOWED: 3 HOURS

INFORMATION FOR CANDIDATES

1. You have 10 minutes to read the paper. You must not begin writing in the answer booklet during this time.
2. **ANSWER ALL QUESTIONS.**
3. All answers must be written on the answer book 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 are not allowed.
6. Show all working and calculations in the answer book.
7. Data required is given on the data sheet.

MARKING SCHEME:

Question 1	[17 marks]
Question 2	[18 marks]
Question 3	[15 marks]
Question 4	[11 marks]
Question 5	[15 marks]
Question 6	[14 marks]
Question 7	[10 marks]

ANSWER ALL QUESTIONS

1. (a) A piping system handling a $2.5 m^3/hr$ slurry has a nominal bore of 21mm containing 81 m of straight pipe which under goes a 10m vertical lift. The fittings to the pipe network is listed below:

Fitting	EPD
4 x gate valve	10 per item
I x globe valve	200 per item
5 x 90° smooth elbows	15 per item
3 x 90° square elbows	30 per item

Rheological study indicated "n" and "k" values to be 0.80 and 3.0 respectively. Assume that the density and viscosity of the slurry to be $1060 \ kgm^{-3}$ and 31.2×10^{-3} Pa.s respectively. Calculate the following:

(i) Flow velocity, Reynold's number and friction factor. [5 marks]
(ii) Frictional head loss for the system. [6 marks]
(iii) Pump head loss. [2 marks]
(iv) Fluid power. [2 marks]
(v) Mains power if the pump is 65 % efficient. [1 mark]

(b) What is the flow behavior of the fluid in 1 (a)? [1 mark]

(Total = 17 marks)

2. (a) Briefly discuss the operating principles of the following:

(i) Positive displacement pump. [3 marks]
(ii) Centrifugal pump. [3 marks]

(b) Compare and contrast between:

(i) Normal and shear stress. [2 marks]
(ii) Cross sectional and wetted flow areas. [2 marks]

(c) With the aid of diagrams discuss in details the difference between orifice and venture meters. Comment on their C_D values. [4 marks]

(d) Discuss how pumping cost can be minimized when designing pipelines. [4 marks]

(Total = 18 marks)

3. (a) Discuss the operating principles of the following heat exchangers and their applications:

   (i) Plate heat exchangers. [4 marks]
   (ii) Scraped surface heat exchangers. [3 marks]

(b) IFC's waste water treatment plant receives an aqueous waste stream at a flow rate of 12,700 kg/h at a temperature of 60°C. Before further treatment this liquor is to be cooled to 40°C using water at 15°C in a concentric pipe heat exchanger. The cooling water flows in the annular space created by the two pipes in a counter-current manner at a flow rate of 21,300 kg/h. The waste stream flows in the inner tube which has inner diameter and wall thickness of 76 mm and 12.7 mm respectively. The water side film heat transfer coefficient is estimated at 5 $kWm^{-2}{}^{o}C^{-1}$. Calculate the length of pipe required for this duty and state any assumptions.

The following data are essential:

Thermal conductivity of the pipe wall:	45.7 $Wm^{-1}{}^{o}C^{-1}$.
Specific heat of the cooling water:	4.2 $kJkg^{-1}{}^{o}C^{-1}$.
Density of the waste stream:	1.1×10^{3} kgm^{-3}.
Viscosity of the waste stream:	0.012 Nsm^{-2}.
Specific heat of the waste stream:	1.5 $kJkg^{-1}{}^{o}C^{-1}$.
Thermal conductivity of the waste stream:	0.28 $Wm^{-1}{}^{o}C^{-1}$.

[8 marks]

(Total = 15 marks)

4. (a) Discuss in details how viscosity and composition can affect flow behavior of fluids. [5 marks]

(b) State the difference between time independent and time dependent non-Newtonian fluids. [2 marks]

(c) With the aid of shear stress-shear rate plot, identify all the different rheological flow patterns. [4 marks]

(Total = 11 marks)

5. A company is to establish experimental groundwork before launching a new product. The tables below contain the experimental findings.

Table 1.0. Microbial history of bacteria under consideration.

Decimal reduction time of organism (min)	Temperature (°C)
0.020	132
0.105	124
0.400	118
2.90	110
10.00	104
20.00	100
50.00	95

Table 2.0. Heat penetration data at retort temperature of 121°C.

Time from start of process (min)	Temperature at can centre (°C)
0	82
2	95
4	103
6	108
8	111
10	115
12	119
14	120
16	121
18	121
20	121
22(start cooling)	120
24	100

(a) Given the data above , calculate the following under *Cl.botulinum cook.* Use graphical plots to support your answers:

(i) Z and D_{121} for the organism. [4 marks]
(ii) Lethal rate for each temperature. [5 marks]
(iii) Sterilization value of the process. [2 marks]

(b) Critically comment on the acceptability of the operation. [1 mark]

(c) Assume the product obeys a convective heating pattern and needs to be cooled after $F_o = 6$ min instead of cooling as in Table 2.0. Calculate the heating time and comment on the quality and cost of the operation. [3 marks]

(Total = 15 marks)

6. (a) Identify and briefly discuss the TWO prime reasons why food is processed. [3 marks]

(b) Discuss fully THREE modes by which foods are processed. For each of the modes discussed, give an example. [5 marks]

(c) (i) Differentiate between sterilization and commercial sterility. [2 marks]
(ii) With respect to heating, discuss ANY TWO factors that affect length of time required to reach sterilization. [4 marks]

(Total = 14 marks)

7. Mare village had a population of 5000 people in 2010. In 2015 census, the population increased to 10000.

(i) Using formula; $P_{future} = P_{present}(1 + GR)^n$, calculate the population growth rate. [5 marks]
(ii) From the growth rate calculated from 7(a)(i), what will be the population after 5 years from 2015? [5 marks]

(Total = 10 marks)

FORMULAR SHEET

1. $V_t = \frac{D^2 g(\rho_p - \rho_f)}{18\mu}$

2. $F_{xF} = U_{xU} + S_{xs}$

3. $S = \frac{F_{xU} - F_{xF}}{xu}$

4. $A_{min} = \frac{F}{\rho_f . V_t}\left[\frac{xu - x_F}{xu}\right]$

5. $A_{min} = \frac{F}{\rho_f . V_t}\left[\frac{xs - x_F}{xs}\right]$

6. $q = UA\Delta T_m$

7. $q = mC_p\Delta T$

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

9. $\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{ln\left[\frac{\Delta T_1}{\Delta T_2}\right]}$

10. $\Delta T_A = \frac{\Delta T_1 + \Delta T_2}{2}$

11. $Nu = \frac{hD}{k}$

12. $Re = \frac{\rho v D}{\mu}$

13. $P_r = \frac{C_p \mu}{k}$

14. $G_r = \frac{\beta g \Delta T L^3 \rho^2}{\mu^2}$

15. $Nu = C(G_r P_r)^{0.25}$

16. $Nu = C(G_r P_r)^{0.33}$

17. $Nu = 0.023 Re^{0.8} Pr^n$

18. $Nu = 0.028 Re^{0.65} Pr^n$

19. $Nu = 0.36 Re^{0.66} Pr^n$

20. $Nu = 0.26 Re^{0.6} Pr^n$

21. Cold fluid: $n = 0.4$
    Hot fluid: $n = 0.3$

22. Streamline: $C = 0.56$ Turbulent $C = 0.12$

23. Streamline: $C = 0.47$ Turbulent $C = 0.12$

24. $\tau = \mu\dot{\gamma}$

25. $\tau = K\dot{\gamma}^n$

26. $\tau^n = \tau_y^{\ n} + k\dot{\gamma}^n$

27. $\mu_{water} = 0.001 Pa.s$

28. $A = \pi dL$

29. $1/U = f_1 + 1/h_1 + X_w / k_w + 1/h_2 + f_2$

30. 1ft = 0.3048m

31. Density of water = $1000 kgm^{-3}$

32. $\Delta P_f = 2fv^2 L\rho/D$

33. $h_f = \Delta P_f / \rho g$

34. $f = 16Re^{-1}$ (<2100), $f = 0.079Re^{-0.25}$ (>2100)

35. $L = n.D.EPD$

36. $W = hp.Q.\rho.g$

37. $G = Av\rho$, $Q = Av$

38. $hp = v^2/2g + h_{lift} + h_{pres} + h_f$

39. $\sigma = k\dot{\gamma}^n$

40. $Re' = \frac{D^n U^{2-n}\rho}{k[(3n+1)/4n]^n 8^{n-1}}$

41. $V_{sp} = \pi d^3/6$

42. $1 lb_m = 0.4536 kg$

43. $RE = (T_2 - T_1) / (T_3 - T_1) \times 100$

44. $L = 10^{(T-121/10)}$

45. $B = f_h \log(j_h I_h / g)$

46. $I_h = T_r - T_{ih}$

47. $jh = (T_r - T_{pih})/(T_r - T_{ih})$

48. $U = FF_i$

49. $Fi = 10^{(121-Tr/z)}$

50. $j_c = (T_c - T_{pic})/(T_c - T_{ic})$

51. $Pt = B - 0.4I$

Table 1.0. Selected f_h/g and g values when Z = 10°C

f_h/U	Values of g for the following j_c values					
	0.40	0.80	1.00	1.40	1.80	2.00
0.50	0.0411	0.0474	0.0506	0.0570	0.0602	0.0665
0.60	0.0870	0.102	0.109	0.123	0.138	0.145
0.70	0.150	0.176	0.189	0.215	0.241	0.255
0.80	0.226	0.267	0.287	0.328	0.369	0.390
0.90	0.313	0.371	0.400	0.458	0.516	0.545
1.00	0.408	0.485	0.523	0.600	0.676	0.715
2.00	1.53	1.80	1.93	2.21	2.48	2.61
3.00	2.63	3.05	3.26	3.68	4.10	4.31
4.00	3.61	4.14	4.41	4.94	5.48	5.75
5.00	4.44	5.08	5.40	6.03	6.67	6.99
10.0	7.17	8.24	8.78	9.86	10.93	11.47
20.0	9.83	11.55	12.40	14.11	14.97	16.68
30.0	11.5	13.6	14.6	16.8	18.9	19.9
40.0	12.8	15.1	16.3	18.7	21.1	22.3
50.0	13.8	16.4	17.7	20.3	22.8	24.1
100.0	17.6	20.8	22.3	25.4	28.5	30.1
500.0	26.0	30.6	32.9	37.5	42.1	44.4

← j_c

↓ g

Adapted from Stumbo (1973).