THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

FIRST SEMESTER EXAMINATION – 2022

FOOD TECHNOLOGY – 3RD YEAR DEGREE

FT 311 FOOD ENGINEERING II

WEDNESDAY 1ST JUNE 2022 – 8:20 A.M.

TIME ALLOWED: 3 HOURS

INFORMATION FOR CANDIDATES

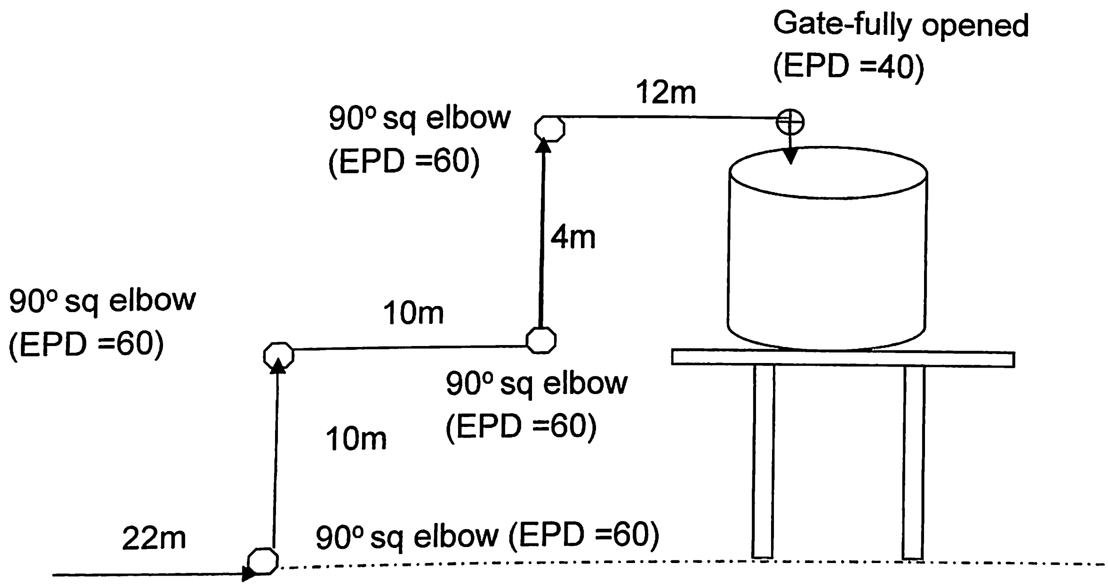
1. You have 10 minutes to read the paper. You must not begin writing in the answer booklet during this time.
2. **ANSWER ALL QUESTIONS.**
3. All answers must be written on the answer book provided.
4. Write your name and number clearly on the front page. **Do it now**.
5. Calculators are permitted in 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	[13 marks]
Question 3	[14 marks]
Question 4	[11 marks]
Question 5	[15 marks]
Question 6	[10 marks]
Question 7	[20 marks]

ANSWER ALL QUESTIONS

1. A piping system handling a 4.5 m^3/hour slurry has a nominal bore of 20 mm with the piping network shown below.



Assume that the density and viscosity of the slurry to be 1000 kgm^{-3} and 1.0×10^{-3} Pa.s respectively. Calculate the following:

(i) Total pipe length, flow velocity, velocity head, Reynold's number and friction factor. [8marks]
(ii) Frictional head loss for the system. [3 marks]
(iii) Pump head loss. [3 marks]
(iv) Fluid power. [2 marks]
(v) Mains power if the pump is 65 % efficient. [1 mark]

(Total = 17 marks)

2. (a) Reynolds number (Re) is the ratio between inertial and viscous forces. Discuss Re values with respect to flow and energy dissipation. [4 marks]

(b) With the aid of a diagram, sketch the velocity profile of a Streamline flow in a pipe. Explain its flow pattern in thermal processing and its importance to quality and safety. [4 marks]

(c) Differentiate between:

(i) Ideal fluids and real fluids. [2 marks]
(ii) Cross sectional area and hydraulic area. [3 marks]

(Total = 13 marks)

3. (a) Discuss the working principle of contact and non-contact types of heat exchangers. Give an example of each this. [4 marks]

(b) A waste water treatment plant receives an aqueous waste stream at a flow rate of 12,900 kg/hour at a temperature of 66 °C. Before further treatment this liquor is to be cooled to 46 °C using water at 13 °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 21,600 kg/hour. The waste stream flows in the inner tube which has inner diameter and wall thickness of 75 mm and 15.7 mm respectively. The water side film heat transfer coefficient is estimated at 7 $kWm^{-2}{}^{o}C^{-1}$.

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 x 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 $Wm^{-1}{}^{o}C^{-1}$.

[10 marks]

(Total = 14 marks)

4. (a) Discuss in detail 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:

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

Use graphical plots to support your answers.

(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_0 = 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) (i) Differentiate between sterilization and commercial sterility. [3 marks]
(ii) With respect to heating, discuss ANY TWO factors that affect length of time required to reach sterilization. [4 marks]

(Total = 10 marks)

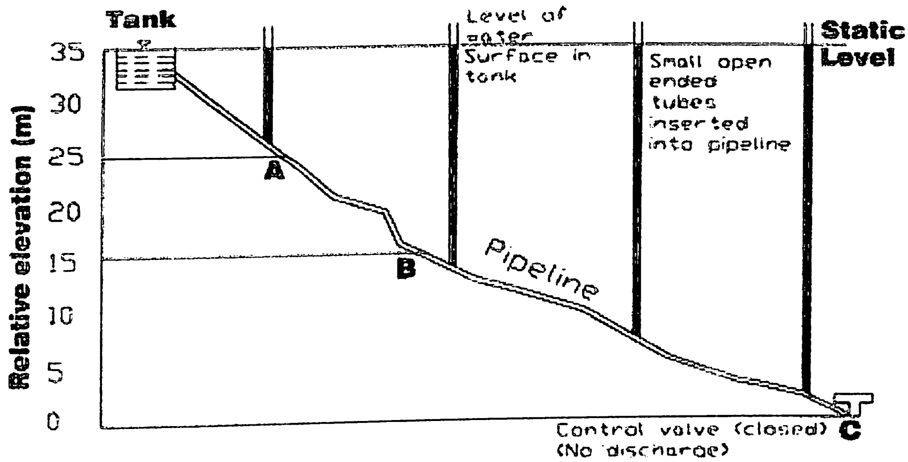
7. (a) BOD test was done on fresh meat waste and toilet waste. Which sample would you expect high BOD value? Explain. [5 marks]

(b) What causes turbidity and how can it be removed? Discuss. [4 marks]

(c) A village had a population of 4500 people in 2015 but census in year 2020 estimated the population to be around 6000 people.

(i) Calculate the population growth rate. [3 marks]
(ii) From the growth rate calculated from 7(c) (i) what will be the population in 2025? [3 marks]

(d) I have a design to consider as given below:



(i) What is the static pressure at Point C? [2 marks]

(ii) Which pipe will I use , assuming that gavanised iron, pressure pipe and PVC pipes have material strengths rated at 300 kPa, 250 kPa and 150 kPa respectively? Justify your answer. [3 marks]

(Total = 20 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. Heating fluid: n = 0.4
Cooing 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. μ_{water} = 0.001Pa.s

28. A = πdL

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. ρ.g

37. G = Avρ, Q = Av

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

39. $\sigma = k\gamma^n$

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. $1lb_m = 0.4536kg$

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. $P_{futre} = P_{present}(1 + GR)^n$

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

Adapted from Stumbo (1973).

← jc

↓ g