

THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

FIRST SEMESTER EXAMINATIONS – 2022

FT 211 – FOOD ENGINEERING I

MONDAY 7<sup>TH</sup> JUNE 2021 – 12:50 PM

TIME ALLOWED: 3 HOURS

**INFORMATION FOR CANDIDATES: -**

1. You will have 10 minutes to read the question paper. You **MUST NOT** begin writing in the answer book during this time.
2. **ANSWER ALL QUESTIONS.**
3. All answers **MUST** be written on the answer book provided
4. Calculators are permitted in the examination room. Lecture notes, notebooks plain papers and textbooks are **NOT** allowed.
5. Mobile phones are not allowed. **SWITCH OFF THE MOBILE PHONES.**
6. Show all workings and calculations in the answer book.
7. **DRAW** the **STRUCTURES** clear and visible.
8. **DO NOT** over write.
9. Write your name and student **ID number** clearly on the front page of the answer book. **DO IT NOW.**

**MARKING SCHEME: TOTAL 100 MARKS**

**ANSWER ALL QUESTIONS**

1. (a) Heat transfer is said to be a dynamic process. Why is this so? [1 mark] .
- (b) Differentiate between steady state and unsteady state heat transfer. [1½ marks]
- (c) Prove that the surface area of a sphere is equal to the curved surface area of a cylinder whose height and diameter is equal to the diameter of the sphere. [3 marks]
- (d) Differentiate between natural and forced convection. [2 marks]
- (e) With illustrations, explain co-current and counter-current heating systems. [6 marks]

- (f) Beans are blanched by immersion in hot water at 96°C. Calculate the temperature at the thermal centre of a bean after three (3) minutes if its diameter is 8 mm, the initial temperature, 20°C and the heat transfer coefficient of the bean surface is 100 W/[m<sup>2</sup>.°C]. Assuming that the physical properties of the beans are fixed with a density of 1050 kg/m<sup>3</sup>, C<sub>p</sub> = 3.7 kJ/[kg.°C] and  $\lambda = 0.5$  W/[m.°C]

[13 marks]

(Total = 26½ marks)

2. (a) At constant absolute humidity, how far would you reduce the temperature of a gas-water vapour mixture from 45°C before it starts losing liquid water if its initial moisture content was 4.215%? Indicate the condition when the mixture loses liquid water. [4 marks]

- (b) Define the terms:
- (i) absolute humidity, [1½ marks]
- (ii) saturated humidity, [1½ marks]
- (iii) wet bulb temperature, [1½ marks]
- (iv) humid heat, [1½ marks]

- (c) With reference to the table (below), what would be your advice, to someone wanting to create an environment that is 60%RH, so to use it for moisture studies?

Salt solutions	Temperature(°C)			
	30	40	50	60
LiCl (Lithium chloride)	0.113	0.112	0.111	0.110
CH <sub>3</sub> COOK (Potassium acetate)	0.216	0.204	0.192	0.180
MgCl <sub>2</sub> ·6H <sub>2</sub> O (Magnesium Chloride)	0.324	0.316	0.305	0.293
K <sub>2</sub> CO <sub>3</sub> (Potassium carbonate)	0.431	0.433	0.427	0.421
Mg(NO <sub>3</sub> ) <sub>2</sub> (Magnesium nitrate)	0.514	0.484	0.454	0.473
NaNO <sub>2</sub> (Sodium nitrite)	0.648	0.609	0.588	0.565
NaCl (Sodium chloride)	0.751	0.747	0.743	0.745
KaCl (Potassium chloride)	0.836	0.823	0.812	0.803

(Greenspan, 1977; Labuza et al., 1985)

[3 marks]

- (d) In a drying operation hot exhaust air is at 46°C, 65%RH and is flowing at 28m<sup>3</sup>/s. Ambient air at 26°C, 90%RH and flowing at 10m<sup>3</sup>/s is to be mixed with the exhaust air before entering the drying chamber, as an attempt to save energy. Determine ALL the properties of the mixed air.

[6 marks]

(Total = 19 marks)

3. (a) What is the ultimate aim of dehydration? [1½ marks]
- (b) Give the properties of a food that affects its drying rate. [2 marks]

(c) Describe the operating mechanism of a fluidized bed dryer. [5 marks]

(d) Turmeric was dried in a dryer using air at 68°C and 0.032 kg/kgDA absolute humidity and flowing at 28,800 m/h. The spice material has a density of 1152 kgm<sup>-3</sup>, moisture content of 82% and spread evenly at 4.5mm thick. If it was to be dried to 11% moisture content, then calculate the duration of constant rate drying time, when heated air is flowing parallel to the bed of spice.

[8 marks]

(Total = 16½ marks)

(a) Distinguish between molecular diffusion and eddy diffusion. With

your answer, demonstrate at least TWO examples of eddy diffusion.

[4 marks]

- (b) With illustration, FULLY explain **two-film-theory** in mass transfer. [3 marks]
- (c) The permeability coefficient for a 0.1 mm thick polyethylene film is being measured by maintaining the moisture vapour gradient across the film in a sealed test apparatus. The moisture on the vapour side of the film is maintained at 90 %RH ( $P = 3.821$  kPa using P-H relationship) and a salt (ZnCl) maintains the opposite side at 10 %RH ( $P = 0.425$  kPa). The area of film exposed to vapour transfer is  $100 \text{ cm}^2$  and a weight gain of 50 grams in the desiccator was recorded after 24 hours. From the given data, calculate the permeability coefficient of the film. [10 marks]

(Total = 17 marks)

5. (a) FULLY explain the functions of a refrigeration cycle. In your explanation, specify the state of refrigerant handled including its magnitude of pressure and temperature. [5 marks]

compression refrigeration system that uses R-134a. The evaporator and condenser temperature are  $-5\text{ }^{\circ}\text{C}$  and  $40\text{ }^{\circ}\text{C}$  respectively. The refrigeration load is 20 tons. Assuming that the unit operates under saturated conditions and the compressor efficiency is 85 %, calculate:



- (i) The mass flow rate of the refrigerant. [2 marks]
- (ii) The value of  $H_1$ ,  $H_2$  and  $H_3$ . [3 marks]
- (iii) The compressor power requirement. [1½ marks]
- (iv) The C.O.P. of this system. [1½ marks]
- (c) A spherical food product is being frozen in an air-blast freezer. The initial product temperature is  $10^\circ\text{C}$  and the cold air is at  $-40^\circ\text{C}$ . The diameter and density are 7cm and  $1000 \text{ kg/m}^3$  respectively. The freezing temperature is  $-1.25^\circ\text{C}$  and the thermal conductivity of the frozen product is  $1.2 \text{ W/[m}\cdot^\circ\text{C]}$  while its latent heat of fusion is  $250 \text{ kJ/kg}$ . Compute the freezing time of this product. [8 marks]