BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

AEH 308

Department Of Engineering and Physics
Bachelor of Science (Honours) in Agricultural Engineering
Food Engineering

3 HOURS (100 MARKS)

INSTRUCTIONS

Answer any *FOUR* questions. Each question carries 25 marks.

Question 1
a. Briefly explain three objectives of most heat transfer operations in food processing. [6 marks]
b. A wet food product contains 70% water. After drying, it is found that 80% of original water has been removed. Determine:
   i.   mass of water removed per kilogram of wet food, and [2 marks]
   ii. composition of dried food. [3 marks]
c. The volumetric flow rate of beer flowing in a pipe is 1.8 L/s. If the inside diameter of the pipe is 3 cm and the density of beer is 1000 kg/m^3, calculate:
   i.   the average velocity of beer, [2 marks]
   ii. the mass flow rate of beer, and [2 marks]
   iii. the velocity for the same volumetric flow rate if another pipe with a diameter of 1.5 cm is used. [2 marks]
d. Explain four functional properties of ingredients used in meat processing. [8 marks]

Question 2
a. Determine the convective heat transfer coefficient of a metal plate when the rate of heat transfer per unit area is 1000 W/m^2. It is given that the surface temperature of plate is 120°C, and ambient temperature is 20°C. [3 marks]
b. With the aid of practical examples, describe two categories of the food drying process. [6 marks]
c. Explain the functions of the following major components of a microwave oven:
   i.   Power supply, [2 marks]
   ii. Power tube, [3 marks]
   iii. Wave guide, [3 marks]
   iv. Stirrer, and [3 marks]
   v.   Oven cavity. [5 marks]

Question 3
a. Describe three ways in which fermentation causes changes in food quality. [6 marks]
b. An ultra-high pressure process is being used to reduce the population of spoilage microorganisms in a food product. The process occurs as follows:

Time (min)	Pressure (MPa)
0	0
1	100
2	200
3	300
4	400
5	400
6	400
7	400
8	200
9	100
10	0

    Estimate the reduction in microbial population that occurs as a result of this process, when the initial population is 2×10^3. It is given that the response of the spoilage microorganism to the pressure treatment is described by $D_{200} = 60$ min and $z_p = 130$ MPa. **[8 marks]**

  c. In wine processing, grape juice is preserved at room temperature by treatment with SO_2. It is desired to strip some of the SO_2 from the sulphured juice. The stripping of the juice will be carried out with a counter-current flow of air in a tray column. The air has a temperature of 25°C and contains water vapour at equilibrium with liquid juice at this temperature. The juice flow rate is $0.56 m^3 s^{-1}$. The SO_2 concentration in juice (mole fraction) is to be reduced from 10^{-3} to 10^{-6}. The initial and final concentrations of SO_2 in air are $y_i = 0$ and $y_o = 0.75 \times 10^{-3}$ (mole fraction). If the partitioning coefficient is 1 (mole fraction c_e/c_r basis), calculate:

     i.   the air flow rate, **[4 marks]**

     ii.   separation factor (S) and **[2 marks]**

     iii. the number of equilibrium stages. **[5 marks]**

Question 4

  a. Describe three factors that affect chilling rates of a food product. **[6 marks]**

  b. Briefly explain the four factors that affect the rate of extraction separation process. **[8 marks]**

  c. Calculate the freezing time of a pizza 3 cm thick being frozen in a cold stream at -20°C, and using Plank equation. The frozen pizza has a freezing point of -1.0°C, density $\rho = 1000 kg/m^3$, and thermal conductivity of $1 W/(mK)$. The heat transfer coefficient in the cold air is $20 W/(m^2K)$. The flat surface of the pizza is much higher than the thickness (an infinite plate). **[11 marks]**

Question 5

  a. Heated air at 50°C and 10% relative humidity is used to dry rice in a bin dryer. If the air exits the bin under saturated conditions, determine the amount of water removed per kg of dry air. **[5 marks]**

  b. In efforts 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:
  i.   the dry bulb temperature, and   [4 marks]
  ii. humidity ratio of the mixed air.   [4 marks]
c. With the aid of diagrams, explain the principle of operation of two types of machines that are commonly used as huskers.   [12 marks]

Question 6

a. The solid particles in a liquid-solid suspension are to be separated by centrifugal force. The particles are 100 microns in diameter with a density of 800 kg/m^3. The liquid is water with a density of 993 kg/m^3, viscocity of 5.95×10^{-4} kg/ms and the effective radius for separation is 7.5 cm. If the required velocity for separation is 0.03 m/s, determine the required rotation speed for the centrifuge.   [5 marks]

b. The concentration of whey is being accomplished by using an ultrafiltration membrane to separate water. The 10 kg/min feed stream has 6% total solids and is being increased to 20% total solids. The membrane tube has a 5 cm inside diameter, and the pressure difference applied is 2000 kPa. If permeability constant is 4×10^{-5} kg H_2O/(m^2 kPa s), calculate:
  i.   the flux of water through the membrane, and   [5 marks]
  ii. the length of the membrane tube.   [5 marks]

c. With the aid of diagrams, describe the operation of a mechanical compression refrigeration system.   [10 marks]

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