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)

JUN 2024

INSTRUCTIONS

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

Question 1

a. Use a Pearson Square to calculate the amounts of orange juice (10% sugar content) and sugar syrup (60% sugar content) needed to produce 50 kg of fruit squash containing 15% sugar. **[5 marks]**

b. Peas which have an average diameter of 6 mm and a density of 880 kgm^{-3} are dried in a fluidised-bed drier. The minimum voidage is 0.4 and the cross-sectional area of the bed is $0.25m^2$. Calculate the minimum air velocity needed to fluidise the bed if the air density is 0.96 kg m^{-3} and the air viscosity is 2.15×10^{-5} N s m^{-2}. **[5 marks]**

c. Calculate the component mass balance for mixing ingredients to make 25 kg of beef sausages having a fat content of 30%, using fresh beef meat and beef fat. Typically, beef meat contains 18% protein, 12% fat and 68% water and beef fat contains 78% fat, 12% water and 5% protein. **[5 marks]**

d. Briefly explain five factors that affect the duration of completely frying foods. **[10 marks]**

Question 2

a. Highlight five main advantages of fermentation as a method of food processing. **[5 marks]**

b. Briefly explain four factors that affect the rate of food separation through a screen. **[8 marks]**

c. Brewers' yeast is grown continuously in a fermenter with an operating volume of 12 m^3. The residence time is 20 h and the yeast has a doubling time of 3.2 h. If a 2% inoculum, which contains 5% yeast cells is mixed with the substrate, calculate the mass of yeast harvested from the fermenter per hour. It is given that the density of broth is 1010 kgm^{-3}. **[12 marks]**

Question 3

a. Milk containing 3.7% fat and 12.8% total solids is to be evaporated to a produce a product containing 7.9% fat. Assuming that there are no losses during the process, calculate:

i. the yield of product from 100 kg of milk and **[5 marks]**

ii. the total solids concentration in the final product. **[5 marks]**

b. Briefly describe five methods of peeling fruits and vegetables. **[15 marks]**

Question 4

a. Corn meal with a moisture content of 18% (wb) is being extruded through a metering zone of an extruder with the following dimensions of the channel: width 8 cm, height 3 cm, length 65 cm. The wall velocity is estimated to be 0.35 m/s. The rheological properties of the extrudate can be estimated by a viscosity of 66,700 Pa s and a density of 1980 kg/m^3. If the pressure drop is maintained at 3500 kPa, calculate the mass flow rate of extrudate through the die. **[5 marks]**

b. Explain four factors that affect the degree of mixing solid food particles. **[8 marks]**

c. Calculate the size of the motor required to blend olive oil and rape-seed oil in a ratio of 1 to 5 by a propeller agitator 20 cm in diameter operating at 750 rpm in a cylindrical tank of 1 m diameter at 20°C. It is given that P_o is 0.5, the viscosity of olive oil at 20°C is 0.084 Nsm^{-2}, the density of olive oil 910 kg m^{-3}, the viscosity of rape-seed oil 0.118 Nsm^{-2} and the density of rapeseed oil 900 kg m^{-3}. **[12 marks]**

Question 5

a. Highlight two advantages of ohmic heating as compared to microwave heating. **[2 marks]**

b. An 8 kW oven has a hearth area of 4 m^2 and operates at 210°C. It is loaded with two batches of bread dough in baking tins; 150 loaves on the first batch and 120 loaves on the second batch. The surface of each loaf measures 12 cm x 20 cm. Assuming that the emissivity of dough is 0.85, that the dough bakes at 100°C, and that 90% of the heat is transmitted in the form of radiant energy, calculate the efficiency of energy use for each batch. **[10 marks]**

c. Beer with a specific gravity of 1.042 and a viscosity of 1.40 x10^{-3}N s m^{-2} contains 1.5% solids which have a density of 1160 kg m^{-3}. It is clarified at the rate of 240 l h^{-1} in a bowl centrifuge which has an operating volume of 0.09 m^3 and a speed of 10 000rpm. The bowl has a diameter of 5.5 cm and is fitted with a 4 cm outlet. If the bowl speed is increased to 15 000 rpm, calculate:

i. the new feed rate, and **[7 marks]**

ii. minimum rev particle size that can be removed at the new speed. **[6 marks]**

Question 6

a. Explain four factors that influence the rate of heat transfer when freezing foodstuffs. **[8 marks]**

b. Pulp which contains 15% solids is filtered in a plate and frame fitter press with a pressure difference of 290 Pa and a 5.5 m^2 filter area. The masses of filtrate are shown below for a 1.5 h cycle.

Time (min)	7.5	30.4	50	90
Mass of filtrate (kg)	1800	3800	4900	6800

If the cake is incompressible and the viscosity of the filtrate is 1.33 x 10^{-3}Nsm^{-2}, calculate:

i. the specific resistance of the cake, and **[10 marks]**

ii. the volume of filtrate that would be obtained if the cycle time were reduced to 45 min. **[7 marks]**

End of paper

FOOD ENGINEERING (AEH308)

MATHEMATICAL FORMULAE

GRINDING AND CUTTING

$dE/dL = KL^n$

Kick

$K = K_K f_c$

$dE/dL = K_K f_c L^{-1}$

$E = K_K f_c \log_e(L_1/L_2)$ **[law]**

Rittinger

$K = K_R f_c$

$dE/dL = K_R f_c L^{-2}$

$E = K_R f_c(1/L_2 - 1/L_1)$ **[law]**

Bond

$E = E_i\,(100/L_2)^{1/2}[1 - (1/q^{1/2})]$ **[law]**

$q = L_1/L_2$

Modification of the grinding energy equations

Energy required E (kWh/kg) for reducing particle size from x_1 to x_2

Rittinger $E = K_R\left(\frac{1}{x_2} - \frac{1}{x_1}\right)$

Kick $E = K_k \ln\left(\frac{x_1}{x_2}\right)$

Bond $E = K_B\left[\left(\frac{1}{x_2}\right)^{1/2} - \left(\frac{1}{x_1}\right)^{1/2}\right]$

EXTRACTION / LEACHING / WASHING

$$\alpha = \frac{Ce}{Cr}$$

$\Phi vfCf + \Phi vsCs = \Phi veCe + \Phi vrCr$

$$\frac{\text{Amount extracted}}{\text{Amount in raffinate}} = \frac{\phi veCe}{\phi vrCr} = \alpha\frac{\phi ve}{\phi vr} = S$$

NB// for single stage

$$S = \frac{Vs}{Vr}$$

$$\text{Non extracted fraction} = 1 - f = \frac{Cr}{Cf} = \frac{1}{1+S}$$

Where f=extracted fraction

$$f = \frac{\text{amount extracted}}{\text{amount in feed}} = \frac{\phi veCe}{\phi vfCf}$$

Therefore for only 1 stage, $f = \frac{S}{S+1}$

For multistage:

$$N = \frac{\ln\left[\left(\frac{S-1}{1-f}\right)+1\right]}{\ln S} - 1$$

REFRIGERATION CHILLING AND FREEZING

Plank's equation

$$t_f = \left[\frac{(\rho\Delta H_L)}{(T_f - T_a)}\right]\left[\left(\frac{2\Pr}{h}\right)+\left(\frac{4Rr^2}{\lambda}\right)\right]$$

ΔH_L= the latent heat of crystallisation of ice (334kJ/kg)

Shape factors

	Shape		
	Sphere	Infinite Plate	Infinite Cylinder
Shape factor	P=1/6, R=1/24	P=1/16, R=1/24	P=1/16, R=1/24

Pham's equation

$$t_f = \frac{1}{E}\left[\left(\frac{\Delta H_1}{\Delta T_1}\right)+\left(\frac{\Delta H_2}{\Delta T_2}\right)\right]\left[\left(\frac{r}{h}\right)+\left(\frac{r^2}{2\lambda}\right)\right]$$

$\Delta T_1=0.5(T_i+T_{fm})-T_a$
$\Delta T_2=T_{fm}-T_a$
$\Delta H_1=\rho C_{pu}(T_i-T_{fin})$
$\Delta H_2=\rho\Delta H_L+\rho C_{pf}(T_{fm}-T_{fin})$
$T_{fm}=1.8+0.263T_{fin}+0.105T_a$

$$E = 1+\left[\frac{\left(1+\left(\frac{2}{\beta_i}\right)\right)}{\left(\beta_1^{\,2}+\left(\frac{2\beta_1}{\beta_i}\right)\right)}+\frac{\left(1+\left(\frac{2}{\beta_1}\right)\right)}{\left(\beta_2^{\,2}+\left(\frac{2\beta_2}{\beta_i}\right)\right)}\right]$$

The shape $\beta_1=A/(\pi r^2)$
$B_2=3V/(4\pi\beta_1 r^3)$
$B_i=(hr)/\lambda$, Biot number

SEDIMENTATION

$$u=\frac{\left[d_{st}^2(\rho_s-\rho)g\right]}{18\mu}$$

FILTRATION

$$\frac{\delta V}{\delta t}=\frac{(A\Delta P)}{R}$$

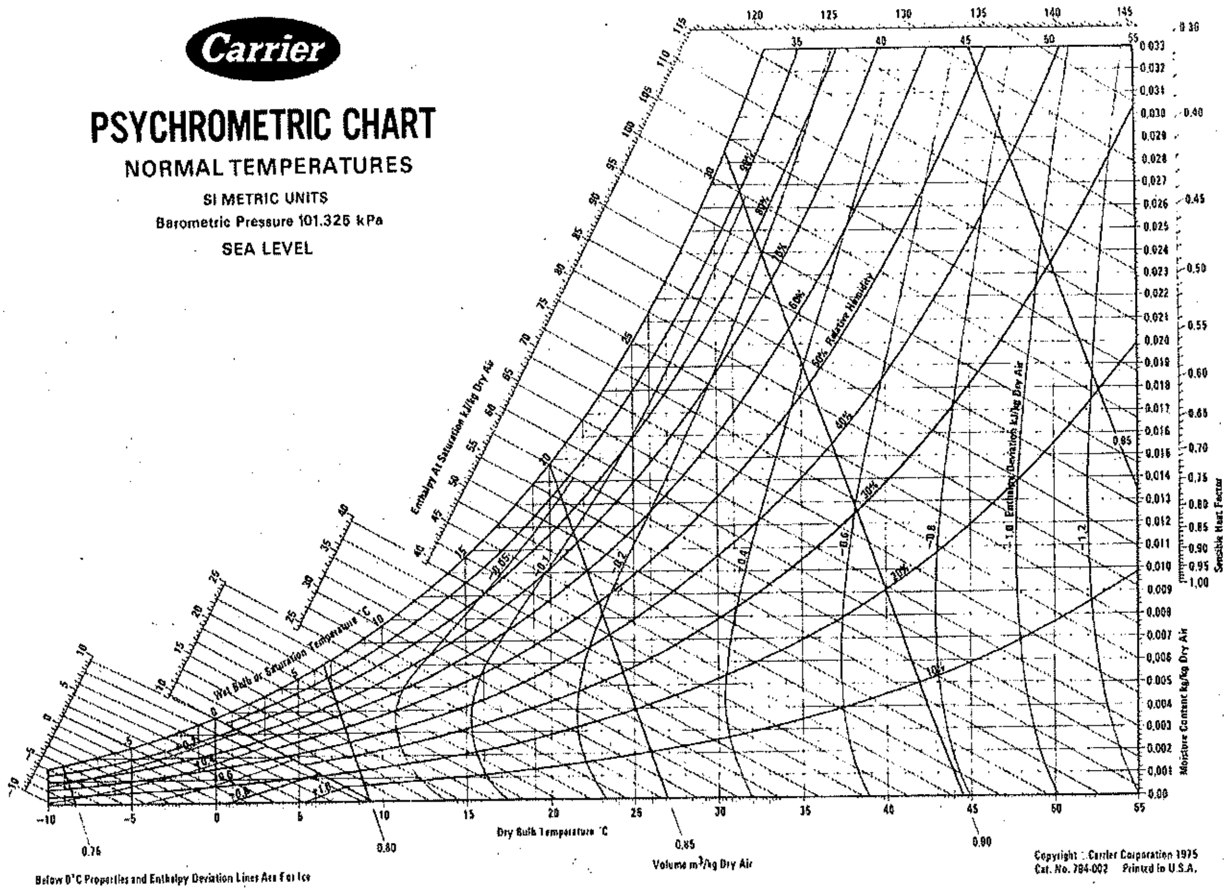
$$R=\mu r(L_c+L)$$

$$L_c=\frac{wV}{A}$$

$$R=\mu r[w\left(\frac{V}{A}\right)+L]$$

$$\frac{\delta V}{\delta t}=\frac{A\Delta P}{\mu r[w\left(\frac{V}{A}\right)+L]}$$

$$\Delta P=\frac{V}{At}\times\mu r\left[w\left(\frac{V}{A}\right)+L\right]$$



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