



UNIVERSITY OF GHANA
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B.Sc. ENGINEERING FIRST SEMESTER EXAMINATIONS: 2016/2017

DEPARTMENT OF FOOD PROCESS ENGINEERING

FPEN 401: FOOD PLANT DESIGN AND ECONOMICS (3 Credits)

INSTRUCTIONS: ANSWER THREE (3) QUESTIONS

TIME ALLOWED: TWO (2) HOURS

1. An existing plate heat exchanger in a factory is used to heat orange juice. The orange juice stream which flows at a rate of F (kg/s) enters the heat exchanger at a temperature of T_1 ($^{\circ}\text{C}$) and is heated up to a temperature of T_2 ($^{\circ}\text{C}$) before exiting. The hot water stream which provides the heat enters and leaves the plate heat exchanger at a temperature of T_{w1} ($^{\circ}\text{C}$) and T_{w2} ($^{\circ}\text{C}$) respectively. The hot water flows at a rate of F_w (kg/s). The hot water stream flows countercurrent to the orange juice stream.

Process Variables	Technical Data	Design Variables
$F = 12 \text{ kg/s}$	$\rho = 1000 \text{ kg/m}^3$	$u = 3.0 \text{ m/s}$
$T_1 = 55^{\circ}\text{C}$	$\rho_w = 960 \text{ kg/m}^3$	$b = 1 \text{ mm}$
$T_2 = 90^{\circ}\text{C}$	$C_{p,w} = 4.18 \text{ KJ/kg K}$	$n = 5$
$T_{w2} = 95^{\circ}\text{C}$	$C_p = 3.86 \text{ KJ/Kg K}$	$L = 0.3 \text{ m}$
	$U = 4230 \text{ W/m}^2\text{k}$	

Determine the flowrate of the hot water stream and the inlet temperature of the hot water stream (T_{w1} $^{\circ}\text{C}$).

- 2.
- a. Suppose you expect to receive the following future cash flows at the end of the years indicated: GHC 1800 in year 2, GHC 4200 in year 4, GHC 2,700 in year 5, and GHC 9000 in year 9. If the interest rate is 9% per year, what is the value of the four flows at year 3?

- b. A rotary dryer is used to dry Gari. Using the process specification, process data and design variables given below, calculate:

Process Specifications	Process Data
$F = 700 \text{ kg/kg db}$ Final moisture content, $X = 0.16 \text{ kg/kg db}$ Material characteristic size, $d = 0.01 \text{ m}$ Ambient temperature, $T_o = 26^\circ\text{C}$ Ambient humidity, $Y_o = 0.03$ Heating stream temperature, $T_s = 160^\circ\text{C}$ $P = 1.00 \text{ bar}$	<i>Specific heat (kJ/kg K)</i> Water, $C_{pL} = 4.2$ Water vapour, $C_{pV} = 1.90$ Air, $C_{pA} = 1.00$ $C_{pS} = 2.0$ Dry material = 3.73 <i>Latent Heat (MJ/kg)</i> Steam condensation at 0°C , $H_o = 2.50$
Design variables	
Drying air humidity, $Y = 0.66 \text{ kg/kg db}$ Drying air velocity, $V = 1.6 \text{ m/s}$ Dryer diameter, $D = 2.0 \text{ m}$ $L = 6 \text{ m}$ $Q = 300 \text{ kW}$ $F = 1.3 \text{ Fa}$ $A_s = 50 \text{ m}^2$	<i>Heat transfer coefficient</i> Heat transfer coefficients ($\text{KW/m}^2\text{K}$) Air heater, $U_s = 0.1$

- i. the air flow rate
- ii. the different thermal energies (Q_{we} , Q_{ah} , Q_{sh}) and thermal efficiency
- iii. the volume of the rotary dryer

3.

- a. At what interest rate per year compounded continuously would an amount of money deposited in a savings account be five times the original amount at the end of five years? What is the effective annual interest rate?
- b. Food Research Institute is considering investing in a new cereal baby food named *Babymix*. Using the following information below, determine:

Working capital (C_w) = 15% of C_T (Total initial capital investment)

Service life = 5 years

Salvage value at the end of the service life = GHC 50,000

Market rate (hurdle rate) = 11%

Internal rate of return (IRR) = 12%

Tax rate = 25%

Depreciation = GHC 140,000 /year

Year	Profit before tax, GHC
1	80,000
2	95,000
3	110,000
4	160,000
5	200,000

- iv. C_T (total initial capital investment)
- v. Return on initial investment (ROI)
- vi. Net present value (NPV)
- vii. Profitability index (PI)
- viii. Payback period (PBP)
- ix. Comment on the financial viability of the project proposal

4.

- a. A new building is expected to cost GHC 1,000,000 and would last for 60 years, assuming that GHC 50,000 is spent on a major rehabilitation at the end of 30 years. Routine maintenance and management expenses are expected to cost GHC 1,000 per year. The building is expected to be leased to the Department of Food Process Engineering for the life of the building. What is the yearly payment that would be equivalent to these costs over the 60-year life of the building, assuming a discount rate of 9% (ignore taxes, inflation, depreciation etc.).
- b. A Food Company is considering a project proposal for a newly formulated food product, AA. The initial fixed capital investment is GHC 18,000,000 and the working capital is GHC 2,000,000. The plant can process 72,000 kg of food in an hour, and will operate 4,000 hours per year. The expected annual expenses (excluding depreciation costs) is GHC 6,000,000 per year. The plant is expected to have a service life of ten years. The depreciation is GHC 1,500, 000. The tax rate is 25%.
 - i. If the required annual rate of return after tax (hurdle rate) is 18%, calculate the minimum amount the food company should charge per customer per kilogram of food product, AA.
 - (A) using the return on initial investment method
 - (B) using the NPV method
 - ii. How would the hurdle rate change if an inflation rate of 4% is considered? The hurdle rate of 18% did not include the inflation rate of 4%.