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B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

August 2024 Supplementary Examinations

Programme: B.E. **Semester: V**
Branch: Chemical Engineering **Duration: 3 hrs.**
Course Code: 19CH5DELB2 **Max Marks: 100**
Course: Optimization of Chemical Processes

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

UNIT - I

1 a) Looking forward to retirement, you wish to accumulate Rs. 6,00,000 after 15 years by making deposits in an account that pays 10 % interest compounded semi-annually. You open the account with an initial deposit of Rs. 32,000 and intend to make semi-annual deposits after every 6 months, from your profit-sharing bonus pay checks. **10**

i. Calculate amount deposited semi-annually to the account.
ii. Draw the time-line cash flow diagram.

b) List the applications of optimization in different chemical processes. **05**

c) Illustrate any two methods used to measure profitability in any process industry. **05**

UNIT - II

2 a) Evaluate if the given objective functions are convex or concave in nature. **10**

i. $f(x_1, x_2) = (x_1 - x_2)^2 + {x_2}^2$
ii. $f(x_1, x_2, x_3) = {x_1}^2 + {x_2}^2 + {x_3}^2$
iii. $f(x_1, x_2) = e^{x_1} + e^{x_2}$

b) Laboratory filtration study is to be carried out at constant rate. The filtration time required is expressed as $t_f = \beta \times \left\{\frac{\Delta P_c \times A^2}{\mu \times M^2 \times c}\right\} \times x_c \times e^{(-a x_c + b)}$. Where t_f = time to build up filter cake, min, $\beta = 3.2 \times 10^{-8}\ kg/m^2$, $\Delta P_c = 20\ kpa$, $A = 250\ \ m^2$, $\mu = 20\ cP$, $M = 75\ kg/min$, $c = 0.01 \frac{kg}{kg\ of\ filtrate}$, $a = 3.643$, $b = 2.680$, and $x_c =$ mass fraction solids in dry cake. Evaluate the maximum time for filtration as a function of x_c by a newton's method. **10**

UNIT - III

3 a) Solve the following constrained optimization problem applying Simplex method. **10**

$$Minimize \;\; f = 3x_1 + x_2 - x_3$$

$$Subject\ to$$

$$x_1 - 2x_2 + x_3 \leq 11$$

$$4x_1 - x_2 - 2x_3 \leq 3$$

$$-2x_1 - 0x_2 + x_3 \leq 1$$

$$x_1, x_2 and\ x_3 \geq 0$$

b) Consider a linear program and plot the geometry of the linear program based on the objective function and constraints given to find the optimal value to maximize the function. **10**

$$\text{maximize} \;\; f = x_1 + 2x_2$$

$$Subject\ to$$

$$-x_1 + 3x_2 \leq 10$$

$$x_1 + x_2 \leq 6$$

$$x_1, and\ x_2 \geq 0$$

UNIT - IV

4 a) Explain the steps involved in optimization of flow rates in a liquid-liquid extraction column. **10**

b) Consider a steady state operation of multiple effect evaporator. The evaporator is used to concentrate an inorganic salt from 0.1 to 1.0 wt. %. The capacity of the plant is 2 million gallons /day. The process variables are given below. Apply the heat and material balance to optimize the operation of the given multistage evaporator. **10**

Data: U = 531 $\frac{W}{m^2 K}$, $C_s =$ cost of steam required (\$/ kg), $C_c = \$\,6.25/m^2$, $C_E = \$\,7000/stage$, $C_{pf} = 4.389 \frac{kJ}{kg\ K}$, $Q = 2.78 \times 10^8\ W$, P = performance ratio, $q_e =$ total kg of water evaporated per hr, $T_b = 4.3\ K$, ΔT_f = 394 K, $\Delta H_v = 2326\ kJ/kg$, $\Delta H_{lout} = 749\ kJ/kg$, $\Delta H_{lin} = 163\ kJ/kg$, n = number of stages.

OR

5 a) Develop the objective function and constrained equations for optimal design and operation of a multi-stage distillation column. **10**

b) Power generating system which has boiler, turbine, generator, condenser, storage tank, and other auxiliary equipment. The process variables are listed below. Apply energy balance to develop an objective function for optimal recovery of waste heat and minimize the resulting objective function to estimate the optimal value of working fluid temperature. **10**

Data given: U = f (working fluid and operating temp), $C_A =$ cost per unit area of the heat exchanger, $r =$ annual capital investment, $C_b =$ annual capital cost for boilers, $C_{op} =$ operating cost, $\eta =$ overall system efficiency, t = operating time in hrs, $\Delta w =$ power from the boiler, and $C_H =$ value of the power (\$/ kW. h).

UNIT - V

6 a) Consider a fixed bed filter. The capacity of the bed is 10 Mega litters per min to filter the given slurry solution. Time taken to give back wash is 10 min, volume of backwash water used is 8.15 m^3, cost of pumping the feed solution is 0.03 \$/kWh, efficiency of the pump is 0.8, head loos in the pump is 33.5 m, capital recovery factor for filter equipment is 0.134, empirical constant for capital investment is 6175 \$/m^2 bed, and exponential constant for fixed capital cost is 0.86. Derive an expression for economical operation of the bed filter in terms of total cost of operation. **10**

b) The feed stream includes ethane, propane, debutanized natural gasoline (DNG), and gas oil, some of which are fed simultaneously. Based on plant data, eight products are produced in varying proportions. The capacity to run gas feeds through the cracker is 200,000 kg/stream hour (total flow based on an average mixture). The maximum amount of ethane, propane, gas oil and DNG are feed into the cracker to operate cracker to its full capacity are 1.1, 0.9, 0.9, and 1 time the actual flow rate of the respective reactants. Optimize the operation of a thermal cracker for economical operations considering only cracker capacity as constraint. The product yield fractions are given the table below. **10**

Yield structure: (wt. fraction)

	Feed			
Product	**Ethane**	**Propane**	**Gas oil**	**DNG**
Methane	0.07	0.25	0.10	0.15
Ethane	0.40	0.06	0.04	0.05
Ethylene	0.50	0.35	0.20	0.25
Propane	—	0.10	0.01	0.01
Propylene	0.01	0.15	0.15	0.18
Butadiene	0.01	0.02	0.04	0.05
Gasoline	0.01	0.07	0.25	0.30
Fuel oil	—	—	0.21	0.01

OR

7 a) The industry wants to design a hydrocarbon piping system in a plant between two points with no change in elevation. The optimal value of the pipe diameter must be estimated to minimize the total cost of the operation. State the assumption made and derive the equation to estimate the optimal pipe diameter. **10**

b) The gas is compressed adiabatically through three staged compressors connected in series. An intermediated cooler is connected after 1^{st} and 2^{nd} stage compressor to cool the gas back to feed gas temperature. Determine equations to optimize the inter-stage pressures to minimize the work for ideal compressible adiabatic flow keeping feed pressure and compressed gas pressure constant after the 3^{rd} stage. **10**

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