S.P & scheme M.M

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MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

II SEMESTER M.TECH. (CHEMICAL ENGINEERING)

MAKEUP EXAMINATIONS, June-July 2023

SUBJECT: Optimization of Chemical Processes [CHE5251]

REVISED CREDIT SYSTEM

Time: 3 Hours Date: 28/06/2023 Time: 9:30 -12:30 PM MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** questions.
- Missing data may be suitably assumed.

1A A Shell and tube heat exchanger has a total cost of $C = \$7000 + \$250D^{2.5}L + \$200D\,L$, where D is the diameter and L is the length. What is the absolute and the relative sensitivity of the total cost with respect to the diameter?
If an inequality constraint exists for the exchanger

$$20\left(\frac{\pi D^2}{4}\right)L \geq 300$$; how must the sensitivity calculation be modified? 05

1B Empirical cost correlations for equipment are often of the following form:

$$\ln C = a_0 + a_1 \ln S + a_2 (\ln S)^2$$

Where **C** is the base cost per unit and S is the size per unit. Obtain an analytical expression for the minimum cost in terms of S, and, if possible, find the expression that gives the value of ***S*** at the minimum cost. Also write down an analytical expression for the relative sensitivity of ***C*** with respect to S. 05

2A What are three major difficulties experienced in formulating optimization problems? 05

2B A reactor converts an organic compound to product P by heating the material in the presence of an additive A. The additive can be injected into the reactor, and steam can be injected into a heating coil inside the reactor to provide heat. Some conversion can be obtained by heating without addition of A, and vice versa. In order to predict the yield of P, Y_P, (lb mole product per lb mole feed), as a function of the mole fraction of A, X_A, and the steam addition ***S*** (in lb/lb mole feed), the following data were obtained. 05

Y_P	X_A	S
0.2	0.3	0
0.3	0	30
0.5	0	60

(a) Fit a linear model : $Y_P = C_0 + C_1 X_A + C_2 S$, that provides a least squares fit to the data.

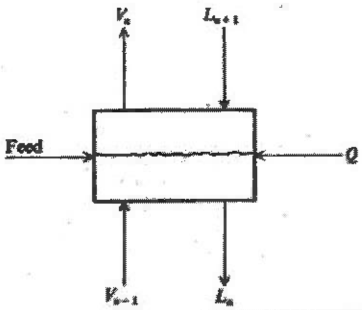
(b) If we require that the model always must fit the point Y_P=00 for X_A= ***S*** = 0, calculate C_0,C_1,C_2 SO that the least squares fit is obtained.

3A Explain the scope of optimization in five different areas with one example for each area 05

3B Find the model parameter of $y = \theta_0 + \theta_1 x$ with the following data using the normal equation of least squares method: i.e. $\hat{\theta} = \left[x^T x\right]^{-1} x^T y$ 05

xi	0.5	1	2.1	3.4
Yi	0.6	1.4	2.0	3.6

4A If you add a feed stream to the equilibrium stage shown in the figure, determine the number of degrees of freedom for a binary mixture (*Q* = heat transferred). 03



4B Determine if the following objective function 04

$$f(\mathrm{x}) = 2x_1^3 + x_2^2 + x_1^2 x_2^2 + 4x_1 x_2 + 3$$

has local minima or maxima. Classify each point clearly.

4C Determine the convexity or concavity of the following objective functions 03

$$(a) f(x_1, x_2) = (x_1 - x_2)^2 + x_2^2$$

$$(b) f(x_1, x_2, x_3) = x_1^2 + x_2^2 + x_3^2$$

$$(c) f(x_1, x_2) = e^{x_1} + e^{x_2}$$

5A The total annual cost of operating a pump and motor ***C*** in a particular piece of equipment is a function of x, the size (horsepower) of the motor, namely 02

$$C = \$500 + 0.9x + \frac{\$0.03}{x}(150,000)$$

Find the motor size that minimizes the total annual cost.

5B Construct Newton's optimization algorithm and Solve the following objective function using Newtons's method. $f(x) = x^2 - 3x - 20$. Consider an initial guess as 0.5 and tolerance (ε) as 10^{-3}. Show a minimum of two iterations of the algorithm. 03

5C A chemical manufacturing firm has discontinued production of a certain unprofitable product line. This has created considerable excess production capacity on the three existing batch production facilities. Management is considering devoting this excess capacity to one or more of three new products: Call them products 1,2, and 3. The available capacity on the existing units that might limit output is summarized in the following table: 05

Unit	***Available time (h/week)***
A	20
B	10
C	5

Each of the three new products requires the following processing time for completion:

	Productivity (h/batch)		
Unit	***Product -1***	***Product-2***	***Product-3***
A	0.8	0.2	0.3
B	0.4	0.3	--
C	0.2	--	0.1

The sales department indicates that the sales potential for products 1 and 2 exceeds the maximum production rate and that the sales potential for product 3 is 20 batches per week. The profit per batch is Rs20, Rs 6, and Rs 8, respectively, on products 1, 2, and 3.

Formulate a linear programming model for determining how much of each product the firm should produce to maximize profit.

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