Code No: NR420805 **Set No.1**

IV B.Tech. II Semester Regular Examinations, April/May -2005

OPTIMIZATION OF CHEMICAL PROCESSES

(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions

All Questions carry equal marks

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1. Suppose you are the manufacturer of phosphorous trichloride, which is sold in barrels at a rate of P barrels per day. The cost per barrel produced is C = 50 + 0.1 P + 9000 / P dollars. For example, for P = 100 barrels / day, C = 150$/barrel.Thesellingpriceperbarrelis$ 300.
Determine :
   (a) The production level giving the minimum cost per barrel.
   (b) The production level which maximizes the profit per day.
   (c) The production level at zero profit.
   (d) Why are the answers at (a) and (b) different?
2. A piece of capital equipment costs $ 6000 and has a service life of three years and no salvage value. Compute the depreciation schedules using the following methods Straight line, Declining Balance, Sum of Years Digits, Accelerated Cost Recovery System. Compare the present worth of each schedule for i=0.07 and i=0.20.
3. Explain the difference between uni model and multi model functions
4. Write in detail the simplex method of solving linear programming problems
5. Describe the procedure for optimizing the recovery of waste heat from a boiler.
6. (a) Discuss about the classification of optimization problems for steady state distillation.
   (b) For the determination of the optimum reflux ratio for a staged distillation column write the equality constraints with the help of a flow sheet. (Use Eduljee correlations)
7. The objective function C for the annual costs of a pipe line transporting of a fluid is given by
$C = C_1D^{1.3}L + 0.142(C_0/\eta)m^{2.8}\mu^{0.2}\rho^{-2.0}D^{-4.8}L$
where C_0 and C_1 are cost coefficients. D and L are diameter and length of the pipe. m, $\rho$and $\mu$are mass flow rate, density and viscosity of the fluid, and η is pump efficiency. The velocity of the fluid, v flowing through the pipe is given by $v = 4m/(\rho \prod D^2)$ Obtain optimal expressions for D_{opt}andv_{opt}.
8. Apply linear programming to maximize a thermal cracker objective function represented by

$$f = 2.84x_1 - 0.22x_2 - 3.33x_3 + 1.09x_4 + 9.39x_5 + 9.51x_6$$

where x_1 = fresh ethane feed, x_2= fresh propane feed, x_3 = gas oil feed, x_4= DNG feed, x_5 = ethane recycle and x_6 = propane recycle.

The objective is subjected to the following constraints:

$1.1x_1+0.9x_2+0.9x_3+1.0x_4+1.1x_5+0.9x6 \leq 200,000$

$0.5x_1+0.35x_2+0.25x_3+0.25x_4+0.5x_5+0.35x6 \leq 100,000$

$0.01x_1+0.15x_2+0.15x_3+0.18x_4+0.01x_5+0.15x_6 \leq 20,000$

$0.4x_1+0.06x_2+0.04x_3+0.05x_4-0.6x_5+0.06x_6= 0$

$0.1x_2+0.041x_3+0.01x_4-0.9x_6= 0$

$x_i \geq 0$

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Code No: NR420805 **Set No.2**

IV B.Tech. II Semester Regular Examinations, April/May -2005
OPTIMIZATION OF CHEMICAL PROCESSES
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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1. (a) Mention briefly the method of determining optimal boiler operating conditions.
   (b) By means of a graphical sketch the common pattern of the thermal efficiency, nitrogen oxide emissions and hydrocarbon emissions as function of air/fuel ratio.
   (c) Represent graphically, the fuel input as a function of the normal practice of boiler operating regime showing discontinuity.

2. Describe two commonly used models of reactors along with their governing equations

3. Does f(x)= x^4 have an extremum. If so what is the value of x* and f(x*) at the extremum.

4. Maximize y = $x_1+3x_2-x_3$
   subject to x1 + 2x2 + x3 = 4
   2x1 + x2$\leq$ 5
   x1, x2, x3 $\geq$ 0
   using the simplex method find the optimize optimum values of x1, x2, x3 and y solve the problem by 1) guessing to obtain an initial basis 2) Using a phase I or phase II method

5. Mention the variables that must be considered by an engineer while making an analysis for the selection of optimal evaporation equipment.

6. For the steady state continuous counter current liquid extraction in a column it was found that the plug flow model was sufficient accurately to represent the data collected. With the help of a schematic diagram, develop the model equations necessary to describe the process and mention the constraints. If the objective is to maximize the total extraction rate, write the objective function. Assume that (i) an analytical solution exists (ii) concentrations are expressed on a solute-free mole basis (iii) the equilibrium relation is a straight line Y* = mX + B and that the operating line is straight.

7. The cost function C representing the annual costs of a pipe line transporting a fluid is given by $C = C_1D^{1.3}L + 0.142(C_0/\eta)m^{2.8}m^{0.2}\rho^{-2.0}D^{-4.8}L$
   where the cost coefficients are considered as C_0= Rs.0.59andC_1= Rs.5.7.The mass flow rate of fluid m = 25 kg/s, density r = 1000kg/m^3, m = 1.08x10^{-3}N/sm^2, the

pumping efficiency $\eta = 0.60$and the pipe length L= 10 m. The fluid velocity is correlated by v = 4m/($\rho \prod$ D2) Find the optimal pipe diameter D_{opt} and optimal fluid velocity v_{opt}.

8. The dynamic model of a continuous flow biological chemostat is given by
$\dot{e} = \gamma k_2 c - De$
$\dot{c} = k_1 s\,(e - c) - (k_2 + k_3)c - Dc$
$\dot{s} = k_1 s\,(e - c) + (k_3 c + D(so - s)$
where e, c and s are biomass, metabolic and substrate concentrations in gmol/lit, respectively. The values of rate constantsk_1, $k_2$and$k_3$are 0.9 lit/mol.h,, $0.7h^{-1}$and 0.0, respectively. The limiting feed substrate concentration s^o =10.0 mol/lit and the parameter $\gamma = 0.09$.The dilution rate D is an independent variable. The objective is to maximize the steady state production of biomass given by f = De. Obtain the steady solution of the system for $0 \leq D \leq 0.6$ and plot the responses of e, c, s and f as a function of D. Find the value of D that provides maximum of f.

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Code No: NR420805 **Set No.3**

IV B.Tech. II Semester Regular Examinations, April/May -2005
OPTIMIZATION OF CHEMICAL PROCESSES
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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1. A packed tubular reactor with radial diffusion is to be optimized. Assume that a single reversible reaction takes place. To set up the problem as a non linear programming problem, write the appropriate balances (constraints) including the initial and boundary conditions using the notation given below: x = extent of the reaction, t = time,
T = dimensionless temperature, r = dimensionless radial coordinate.

2. (a) Develop expressions for the representation of linear data by the method of least squares.
   (b) Fit the model : $y = \beta_0+\beta_1 x$ to the following y (the measured response) and x (the independent variable) data.

X	0	1	2	3	4	5
Y	0	2	4	6	8	10

3. The future worth s of a series of n uniform payments each of amount p is $s = (p/i)[(1+i)^n - 1]$ where i=interstate per period. If i is considered to be the only variable, is it discrete of continuous. Explain repeat for n?

4. Describe in detail the basic concepts involved in linear programming?

5. Enlist the variables that are specified a priori by the designer, the variables to be calculated via optimization and the variables used for minimizing the objective function in the optimization of a shell-and-tube heat exchanger design (single-pass counterflow heat exchanger in which the tube fluid is in turbulent flow but there is no change of phase of fluids in the shell or tubes).

6. (a) Discuss about the classification of optimization problems for steady state distillation.
   (b) describe how the nonlinear regression technique(least squares) can be used to fit vapor-liquid equilibrium data. Use van Laar model with two adjustable parameters to correlate the VLE data.

7. The annual costs of transporting a fluid through a pipe line depends on the diameter of the of the pipe line. The objective function for the annual costs C is a sum of annualized investment charges C_{inv} and pump operating costs C_{op} , which are expressed as
$C_{inv} = C_1 D^{0.3} L$

C_{op}= C0m_Dp/$\rho\eta$
where C_0 and C_1 are cost coefficients, m and r are mass flow rate and density of fluid, h is pump efficiency and L is the length of pipe line. The objective function C includes four variables the pipe diameter D, the velocity v, the pressure drop Δp and the friction factor f. Three of these variables have the following correlations:
$\Delta p = 2f\rho v^2 L/D$
$m = (\rho \prod D^2/4)v$
$f = (0.046\mu^{0.2})/(D^{0.2}v^{0.2}r^{0.2})$
Formulate the objective function by eliminating Δp, v and f, and obtain an expression for the optimal pipe diameter D considering it as the independent variable.

8. Various feeds and product distribution for a thermal cracker which produces olefins are listed in weight fractions in the following table.

			Feed	
Product	Ethane	Propane	Gas Oil	DNG
Ethane	0.40	0.06	0.04	0.05
Ethylene	0.50	0.35	0.20	0.25
Propylene	0.01	0.15	0.15	0.18
Propane	–	0.10	0.01	0.01
Butadiene	0.01	0.02	0.04	0.05
Gasoline	0.01	0.07	0.25	0.30

Methane and fuel oil produced by the cracker are recycled as fuel. All the ethane and propane produced is recycled as feed. The cost of feeds and products are assumed as follows:

Feeds	Cost (Rs/kg)	Products	Cost (Rs/kg)
Ethane	6.55	Ethylene	17.75
Propane	9.73	Propylene	13.79
Gas oil	12.50	Butadiene	26.64
DNG	10.14	Gasoline	9.93

Involve the above data and setup the objective function to maximize the profit of thermal cracker.

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Code No: NR420805 **Set No.4**

IV B.Tech. II Semester Regular Examinations, April/May -2005
OPTIMIZATION OF CHEMICAL PROCESSES
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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1. Explain the scope and hierarchy of optimization.

2. Describe two commonly used models of reactors along with their governing equations

3. For $f(x) = 3x_1^2+2x_1x_2+1.5x_22$ find the equation for the principal axes and determined a transformation $x = V_z$ such that $f = a_{11}z_1^2+a_{22}z_2^2$ thus eliminating the interaction term.

4. Describe in detail the basic concepts involved in linear programming?

5. Give the general procedure for the optimization of number of stages and determining the optimal performance ratio in a multistage evaporator.

6. (a) What are the categories into which optimization problems for steady state distillation are classified in general? Discuss briefly.
   (b) With the help of a schematic diagram, formulate the equality constraints for optimal design and operation of a conventional staged distillation column.

7. The annual costs of transporting a fluid through a pipe line depends on the diameter of the of the pipe line. The objective function for the annual costs C is a sum of annualized investment charges $C_{inv}$and pump operating costs C_{op} , which are expressed as
   $C_{inv}= C_1D^{0.3}L$
   $C_{op}= C0m_Dp/\rho\eta$
   where C_0 and C_1 are cost coefficients, m and r are mass flow rate and density of fluid, h is pump efficiency and L is the length of pipe line. The objective function C includes four variables the pipe diameter D, the velocity v, the pressure drop Δp and the friction factor f. Three of these variables have the following correlations:
   $\Delta p = 2f\rho v^2L/D$
   $m = (\rho \prod D^2/4)v$
   $f = (0.046\mu^{0.2})/(D^{0.2}v^{0.2}r^{0.2})$
   Formulate the objective function by eliminating Δp, v and f, and obtain an expression for the optimal pipe diameter D considering it as the independent variable.

8. Apply linear programming to maximize a thermal cracker objective function represented by
   $f = 2.84x_1-0.22x_2-3.33x_3+1.09x_4+9.39x_5+9.51x_6$

   where x_1 = fresh ethane feed, x_2= fresh propane feed, x_3 = gas oil feed, x_4= DNG feed, x_5 = ethane recycle and x_6 = propane recycle.

The objective is subjected to the following constraints:

$1.1x_1+0.9x_2+0.9x_3+1.0x_4+1.1x_5+0.9x6 \leq 200,000$

$0.5x_1+0.35x_2+0.25x_3+0.25x_4+0.5x_5+0.35x6 \leq 100,000$

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$0.4x_1+0.06x_2+0.04x_3+0.05x_4-0.6x_5+0.06x_6= 0$

$0.1x_2+0.041x_3+0.01x_4-0.9x_6= 0$

$x_i \geq 0$

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