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

IV B.Tech. II Semester Supplementary Examinations, July -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. An organic chemical is produced in a batch reactor. The time required to successfully complete one batch of product depends upon the amount charged to (and product from) the reactor, and it has been correlated to be : t = 2 P0.4, where P is the amount of product in pounds per batch and t is in hours. A certain amount of non-production time is associated with each batch for charging, discharging and minor maintenance, namely 14 h/batch. The operating cost for the batch system is $ 50/hour while operating. The capital costs including storage depend on the size of each batch and have been prorated on an annual basis to be C_I = $ 800 $P^{0.7}$
The annual production required is 300,000 lb/year, and the process can be operated 320 days/year(24 hour/day). Total raw material cost at this production level is $ 400,000 / year.

   (a) Formulate an objective function using P as the only variable.
   (b) Are there constraints on P ?
   (c) Solve for optimum value of P. Check that it is a minimum. Also check application constraints.
   (d) Is this a flat optimum, that is the objective function is insensitive to P? Draw an approxi-mate plot of the respective capital and operating cost components as a function of P.

2. Briefly write about factorial design of experiments, and through an example point out the simplifications that follow.

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

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

5. For a waste heat recovery system the following data are given: Cost per unit area of exchanger, C_A= Rs.20/ft^2
Value of power, incorporating necessary conversion factors to have a consistent set of units, C_H= 1.76x10^{-5}
Average overall heat transfer coefficient, U = 95Btu/(h)(^{o}F)(ft^2)
Number of hours per year of operation, y = 8760 h/year

Annualization factor for capital investment, r = 0.365
Efficiency of overall system, η= 0.7
Condensing temperature, T_2= 600°R
Average hot fluid temperature,T_s= 790°R
Calculate the optimum value of the working fluid temperature, TH.

6. With the help of a schematic diagram, develop the model equations necessary to describe the process of steady state continuous counter current liquid extraction in a column. The plug flow model was found to accurately represent the experimental data. 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 and that the operating line is straight. Write the constraints and the objective function to maximize the total extraction rate.

7. The cost function C representing the annual costs of a pipe line transporting a fluid is given by
$C = C_1D^{1.3}L + 0.142(C_0/\eta)m^{2.8}\mu^{0.2}\rho^{-2.0}D^{-4.8}L$
where the cost coefficients are considered as C_0= Rs. 0.59 and C_1= Rs. 5.7. The mass flow rate of fluid m = 25 kg/s, densityρ= 1000kg/m^3,μ= 1.08x10^{-3}N/sm^2, the pumping efficiency η= 0.60 and the pipe length L= 10 m. Find the optimal pipe diameter D_{opt}

8. The steady state monod chemostat model for substrate mass balance and cell mass balance is described by the following equations : $D(s_f - s) - \frac{\mu_{\max} sx}{y_{x/s}(s+K_s)} = 0$
$\left[\frac{\mu_{\max} s}{K_s+s} - D\right] x + Dx_f = 0$
where x and s are cell and substrate concentrations, respectively and D is the dilution rate. The parameter values are: maximum specific growth rate μ_{max}= 1.0h^{-1}, yield factor $Y_{x/s}$= 0.5,substrate growth rate constant K_s= 0.2g/lit,substrate feed concentration s_f= 10.0g/litand initial cell concentration x_f = 0. The objective is to find the optimal value of D that provide maximum cell production Dx. Obtain the steady state solution for x and s as a function of D, $0 \leq D \leq 1.0$and find the value of D that provide maximum cell production Dx.

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

IV B.Tech. II Semester Supplementary Examinations, July -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) Explain briefly the method of determining the optimum distillation reflux.
   (b) By means of a neat sketch, represent the normal pattern of optimal reflux for different fuel costs.
   (c) Represent by means of a diagram, the common pattern of total profit for different fuel costs.

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. Consider the following objective functions: is it convex ? use eigen values in the analysis $f(x) = 2x_1^2 + 2x_1x_2 + 1.5x_2^2 + 7x_1 + 8x_2 + 24$

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

5. For a waste heat recovery system the following data are given: Cost per unit area of exchanger, C_A= Rs.20/ft^2
   Value of power, incorporating necessary conversion factors to have a consistent set of units, $C_H = 1.76\text{x}10^{-5}$
   Average overall heat transfer coefficient, U = 95Btu/(h)(^{o}F)(ft^2)
   Number of hours per year of operation, y = 8760 h/year
   Annualization factor for capital investment, r = 0.365
   Efficiency of overall system, η= 0.7
   Condensing temperature, T_2= 600^{o}R
   Average hot fluid temperature, T_s= 790^{o}R
   Calculate the optimum value of the working fluid temperature, TH.

6. (a) Discuss about the classification of optimization problems for steady state distillation.
   (b) For optimal design and operation of conventional staged distillation columns formulate the equality constraints with the help of a schematic diagram.

7. The cost function C representing the annual costs of a pipe line transporting a fluid is given by
$C = C_1 D^{1.3} L + 0.142 (C_0/\eta) m^{2.8} \mu^{0.2} \rho^{-2.0} D^{-4.8} L$
where the cost coefficients are considered as C_0= Rs. 0.59 and C_1= Rs. 5.7. The mass flow rate of fluid m = 25 kg/s, densityρ= 1000kg/m^3,μ= 1.08x10^{-3}N/sm^2, the pumping efficiency η= 0.60 and the pipe length L= 10 m. Find the optimal pipe diameter D_{opt}

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.3**

IV B.Tech. II Semester Supplementary Examinations, July -2005
OPTIMIZATION OF CHEMICAL PROCESSES
(Chemical Engineering)

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

Answer any FIVE Questions
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1. The total cost (dollars per year) for pipe line installation/operation for an incompressible fluid can be expressed by:
   $C = C_1D^{1.5}.L + C_2m\Delta p/\rho$
   where $C_1$is the installed cost of the pipe per foot length computed on an annual basis ($C_1D^{1.5}$is expressed in dollars per year per foot length), C_2 is based on \$ 0.05 / kWh, 365 days/year and 60 per cent pump efficiency.; D is the diameter to be optimized; L is the length of the pipe line = 100 miles; m is the mass flow rate = 200,000 lb/h; $\Delta p = 2\rho v^2L/(Dg_c)$ f = pressure drop in psi;$\rho$is the density = 60 lb/ft3; v is the velocity = (4m) / $(\rho\pi D^2)$;f = friction factor = $(0.046\ m^{0.2})/(D^{opt} and v^{opt} C^{opt}.)\mu$ is the viscosity = 1 cP.

   (a) Find general expressions for $D^{opt}v^{opt}andC^{opt}$.
   (b) For$C_1 = 0.3$ (D expressed in inches for installed cost), calculate $D^{opt}andv^{opt}$ for the following values ofμandρ. $\mu = 0.2, 1 and 10 cP\ \rho = 50, 60 and 80 lb/ft^3$

2. Explain the consideration of the time value of money with reference to future worth and present worth.

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

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

5. For a waste heat recovery system the following data are given: Cost per unit area of exchanger, C_A= Rs.20/ft^2
   Value of power, incorporating necessary conversion factors to have a consistent set of units, $C_H = 1.76x10^{-5}$
   Average overall heat transfer coefficient, U = 95Btu/(h)(^{o}F)(ft^2)
   Number of hours per year of operation, y = 8760 h/year
   Annualization factor for capital investment, r = 0.365
   Efficiency of overall system, η= 0.7
   Condensing temperature, T_2= 600^{o}R
   Average hot fluid temperature,T_s= 790^{o}R
   Calculate the optimum value of the working fluid temperature, TH.

6. (a) Categorize the optimization problems for steady state distillation and discuss briefly.
   (b) List the equality constraints for the optimal design and operation of a conventional staged distillation column with a neat schematic diagram.

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
$C_{inv}= C_1D^{0.3}L$
$C_{op}= C0m_{D}p/\rho\eta$
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. 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
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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)
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Involve the above data and setup the objective function to maximize the profit of thermal cracker.

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1. For a two stage adiabatic compressor, where the gas is cooled to the inlet gas temperature between stages, the theoretical work is given by :
   $W = \{kp_1V_1/(k-1)\}[(p_2/p_1)^{\{(k-1)/k\}} - 2 + (p_3/p_2)^{\{(k-1)/k\}}]$

   where $k = C_P/C_{V},_1$ $p_1=$ inlet pressure, p_2 = intermediate stage pressure,

   p_3 = outlet pressure and V_1 = inlet volume.

   We have to optimize the intermediate pressure p_2 so that the work is minimum.

   Show that if p_1 = 1atm. and p_3 = 4 atm, p_2 opt = 2 atm.

2. Discuss the important steps involved in building a model for practical applications.

3. Explain the difference between uni model and multi model functions

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

5. For a waste heat recovery system the following data are given: Cost per unit area of exchanger, C_A= Rs.20/ft^2
   Value of power, incorporating necessary conversion factors to have a consistent set of units, C_H= 1.76x10^{-5}
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   Efficiency of overall system, η= 0.7
   Condensing temperature, T_2= 600^{o}R
   Average hot fluid temperature,T_s= 790^{o}R
   Calculate the optimum value of the working fluid temperature, TH.

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 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:
   $1.1x_1+0.9x_2+0.9x_3+1.0x_4+1.1x_5+0.9x6 \leq 200,000$
   $0.5x_1+0.35x_2+0.25x_3+0.25x_4+0.5x_5+0.35x6 \leq 100,000$
   $0.01x_1+0.15x_2+0.15x_3+0.18x_4+0.01x_5+0.15x_6 \leq 20,000$
   $0.4x_1+0.06x_2+0.04x_3+0.05x_4-0.6x_5+0.06x_6= 0$
   $0.1x_2+0.041x_3+0.01x_4-0.9x_6= 0$
   $x_i \geq 0$

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