Code No: RR420805

Set No. 1

IV B.Tech II Semester Regular Examinations, Apr/May 2006
OPTIMIZATION OF CHEMICAL PROCESS
(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. [16]

2. Explain the consideration of the time value of money with reference to future worth and present worth. [16]

3. For $f(x) = 3x_1^2+2x_1x_2+1.5x_2^2$ 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. [16]

4. Describe in detail the basic concepts involved in linear programming? [16]

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)(°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. [16]

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. [8+8]

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 η= 0.60and 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}. [16]

8. The steady state dependence of chemostat variables, namely, cell mass concentration x and substrate concentration s are expressed by the following equations:

$x = y_{x/s}\left(S_f - \frac{DK_s}{\mu_{\max} - D}\right)$
$S = \frac{DK_s}{\mu_{\max} - D}$
where D is the dilution rate. The parameter values are: maximum specific growth rate $\mu_{\max}$= 1.0h^{-1}, yield factor $Y_{x/s}$= 0.5, substrate growth rate constant K_s= 0.2g/lit and substrate feed concentrations_f= 10.0g/lit. Describe the steady state behavior of x and s as a function of D as D increases from 0 to $\mu_{\max}$. [16]

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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 = $(0.046\ m^{0.2})/(D^{opt}andv^{opt}C^{opt}.)\mu$ is the viscosity = 1 cP.

   (a) Find general expressions for $D^{opt}v^{opt}$andC^{opt}.

   (b) ForC_1 = 0.3 (D expressed in inches for installed cost), calculate D^{opt}andv^{opt} for the following values ofμandρ. μ= 0.2, 1and10cPρ= 50, 60and80lb/ft^3 [16]

2. Discuss the important factors involved in optimizing profitability. [16]

3. Consider the following objective functions: is it convex ? use eigen values in the analysis $f(x) = 2x_1^2+2x_1x_2+1.5x_2^2+7x_1+8x_2+24$ [16]

4. Describe in detail the basic concepts involved in linear programming? [16]

5. (a) How are capacity and economy affected in multiple effect evaporators? What is the effect of boiling point elevation on capacity? Why are multiple effects often economical?

   (b) Write about the procedure for determining the optimum number of effects in a multiple effect evaporator. [8+8]

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. [8+8]

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} [16]

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,, 0.7$h^{-1}$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 $0 \le D \le 0.6$ 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. [16]

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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. [16]

2. Describe two commonly used models of reactors along with their governing equations [16]

3. Explain the difference between uni model and multi model functions [16]

4. Use the simplex procedure with un restricted variables
   minimize f(x) = x1 + 4x2
   subject to x1 + x2 ≤ 3
   $-x1 + x2 \leq 1$
   x1 unrestricted, x2 ≥ 0
   find the optimal values of x1 and x2? [16]

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)(°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. [16]

6. (a) 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) [6]

(b) Develop an expression for the objective function f which is the operating profit given the following data for separating propane and propylene:
C_1 = Reboiler heat cost
C_2 = Condenser cooling cost
C_B= Value of propylene in bottoms
C'_B = Value of propane in bottoms
C_D = Value of propylene in overhead
C'_D = Value of propane in overhead
C_F = Cost per pound of propylene
C'_F = Cost per pound of propane
Q_C = Condenser load requirement
Q_R = Reboiler heat requirement
D, B, F = Distillate flow rate, Bottoms flow rate and Feed rate respectively
X_D, X_B, X_F = Mole fraction of light key in overhead, bottom and feed respectively. [10]

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
$C_{inv}= C_1 D^{0.3} L$
$C_{op}= C0 m_D p/\rho\eta$
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:
$\Delta p = 2f\rho v^2 L/D$
$m = (\rho \prod D^2/4)v$
$f = (0.046\mu^{0.2})/(D^{0.2} v^{0.2} r^{0.2})$
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. [16]

8. The steady state dependence of chemostat variables, namely, cell mass concentration x and substrate concentration s are expressed by the following equations:
$x = y_{x/s}\left[s_f - \frac{DK_3}{\mu_{\max}-D}\right]$
$s = \frac{DK_s}{\mu_{\max}-D}$ where D is the dilution rate. The parameter values are: maximum specific growth rate $\mu_{\max}= 1.0h^{-1}$,yield factor $Y_{x/s}= 0.5$,,substrate growth rate constant Ks=0.2 g/lit and substrate feed concentration $s_f= 10.0$g/lit. The objective is to maximize the rate of cell production Dx. show that and find the value of D_{opt}.
$D_{opt} = \mu_{\max}\left(1 - \sqrt{\frac{K_s}{K_s+s_f}}\right)$ [16]

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1. Describe the general procedure for solving optimization problems, indicating the six steps used to solve optimization problems. [16]

2. Formulate net present value for a project lasting n years with an initial investment I0, interest rate of capital i, constant annual expense E, constant annual revenue A, salvage value S_v, yearly depreciation D_j, and a tax rate t. Compare NPV for tax rates of 0 and 50 percent, S_v, = 0, and straight-line depreciation. Use n = 10 and i = 0.15(r = 0.2). [16]

3. Consider the following objective functions: is it convex ? use eigen values in the analysis $f(x) = 2x_1^2+2x_1x_2+1.5x_2^2+7x_1+8x_2+24$ [16]

4. Describe in detail the basic concepts involved in linear programming? [16]

5. Develop the equation for determining the optimum number of stages and the optimal performance ratio in multiple effect evaporation. [16]

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. [8+8]

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 η= 0.60and 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}. [16]

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:
   $1.1x_1+0.9x_2+0.9x_3+1.0x_4+1.1x_5+0.9x6 \leq 200,000$
   $0.5x_1+0.35x_2+0.25x_3+0.25x_4+0.5x_5+0.35x6 \leq 100,000$

$$0.01x_1+0.15x_2+0.15x_3+0.18x_4+0.01x_5+0.15x_6 \leq 20,000$$
$$0.4x_1+0.06x_2+0.04x_3+0.05x_4-0.6x_5+0.06x_6= 0$$
$$0.1x_2+0.041x_3+0.01x_4-0.9x_6= 0$$
$$x_i \geq 0$$

[16]

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