2017-18
M.TECH. (WINTER SEMESTER) EXAMINATION
PETROLEUM PROCESSING AND PETROCHEMICAL ENGG.
PROCESS DYNAMICS & CONTROL
PK-604 / CH-621

Maximum Marks: 60  Credits: 04  Duration: Two Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No.       Question                                           M.M.

1(a)       What are the three types control configurations used in chemical/petrochemical [03]
            Industries.

1(b)       Develop a linearized model of a Catalytic Cracking Unit. State Assumptions clearly. [07]

OR

1(b’)      Describe the dynamic model of a binary distillation column. State clearly the [05]
            assumptions made.

1(c)       For a liquid tank given in Fig.1, derive the equation for the transfer function and show that \( \tau_p = A \times R \).

![Diagram of liquid tank](image)

Given: \( F = \frac{H}{A} \)

R = resistance to flow

\[ \text{contd... 2} \]
2(a) Discuss the effect of Proportional, Integral and derivative control action on the dynamics of the First order process with \( G_m = G_f = 1.0 \) OR

2(a') Consider a feedback control system given below with the following transfer functions:
\[ G_c = K_c, \ G_v = \frac{1}{2s + 1}, \ G_p = G_d = \frac{1}{5s + 1} \] and \( G_m = \frac{1}{s + 1} \). Find the values of controller gain \( K_c \) that make the feedback control system stable.

![Control System Diagram]

2(b) Consider the transfer function
\[ G(s) = \frac{K_p}{(0.2s + 1)[(6s + 1)(3s + 1)(s + 1)]} \]
Derive an approximate first order plus time delay model using Skogestad’s half rule.

2(e) For the process model \( G = 4e^{-s}/[(10s + 1)(5s + 1)] \), compare PID controller settings using

(i) Zeigler-Nichols (Z-N) settings

(ii) Tyreus-Luyben (T-L) settings. (use \( K_{cu} = 7.88 \) and \( P_u = 11.66 \))

(iii) Direct Synthesis (DS) method with \( \tau_c = 3 \)

For unit step change in both set point and load. Also, \( G_d = G \)

3(a) Discuss in brief Cascade Control for Distillation Column with neat diagram.

3(b) What is adaptive control, and why it is needed in a chemical/Petrochemical process unit?

3(b') Explain in brief with sketch feed forward control scheme for temperature control of a stirred tank heater.

4(a) Find the Inverse z-Transform of
\[ y(z) = \frac{[1 - 0.1z^{-1} + 3z^{-2}]}{[2 + 3z^{-1} + z^{-2} - 0.1z^{-3} + z^{-4}]} \]
by long division method or by partial fraction method.

4(b) Develop a closed loop response of a DDC loop and discuss its important features.
Maximum Marks: 60
Credits: 04
Duration: 3 Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No.                                          M.M.
1(a) Show that for a perfectly mixed CSTR, variance is equal to space time of the reactor. [4]
1(b) Develop the expression for $E(t)$ when a real CSTR is modelled as a CSTR and PFR in series. Draw the RTD curve for a CSTR and a PFR in series. [4]

(c) The first order reaction is carried out in a 10 cm diameter tubular reactor 6.36 m in length. The specific reaction rate is 0.25/min. Following experimental data were obtained from a trace input to this reactor:

<table>
<thead>
<tr>
<th>t(s)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (mg/liter)</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>2.2</td>
<td>1.5</td>
</tr>
<tr>
<td>t(s)</td>
<td>12</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C(mg/liter)</td>
<td>0.6</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculate the conversion using the Tanks in series model and also for a single ideal CSTR.

OR

(c') The elementary reaction

$$A + B \rightarrow C + D$$

[7]
is to be carried out in the CSTR shown schematically in Figure below. There is both bypassing and a stagnant region in this reactor. The tracer output for this reactor is shown in the Table as given below. The measured reactor volume is 1.0 m³ and the flow rate to the reactor is 0.1 m³/min. The reaction rate constant is 0.28 m³/kmol. min. The feed is equimolar in A and B with an entering concentration of A equal to 2.0 kmol/m³. Calculate the conversion that can be expected in this reactor. The entering tracer concentration is \( C_{T0} = 2000 \) mg/dm³.

Table: Tracer data for step input

<table>
<thead>
<tr>
<th>( C_T ) (mg/dm³)</th>
<th>1000</th>
<th>1333</th>
<th>1500</th>
<th>1666</th>
<th>1750</th>
<th>1800</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t ) (min)</td>
<td>4</td>
<td>8</td>
<td>10</td>
<td>14</td>
<td>16</td>
<td>18</td>
</tr>
</tbody>
</table>

2(a) Show that the overall rate of reaction may be increased when the rate of mass transfer to the surface limits the overall rate of reaction? Explain why the mass transfer effects are not important, when the reaction rate is limiting?

(b) What are the commercial applications of catalyst monoliths reactor? Develop the design equation to predict the concentration profile in a parallel plate reactor.

(c) Derive the following expression for the concentration profile in a spherical catalyst pellet for a first order irreversible reaction.

\[ \frac{C_A}{C_{AS}} = \frac{R}{\tau} \left[ \frac{\sinh(\Phi \tau/R)}{\sinh \Phi} \right]. \]
Where $\Phi_1$ is the Thiele modulus.

**OR**

(c') A first order heterogeneous irreversible reaction is taking place within a spherical catalyst pellet which is plated with Pt throughout the pellet. The reactant concentration halfway between the external surface and the center of the pellet is equal to one-tenth the concentration of the pellet's external surface. The concentration at the external surface is 0.001 gmol/dm$^3$, the diameter is 0.0002 cm, and the diffusion coefficient is 0.1 cm$^2$/s.

i. What is the concentration of reactant at a distance of 0.00004 cm in from the external pellet surface?

ii. To what diameter should the pellet be reduced if the effectiveness factor is to be 0.8?

3(a) A first order reversible reaction is to be carried out in a CSTR having volume of 5 m$^3$. The feed enters at 300 °K with volumetric flow rate of 0.2 m$^3$/s and concentration of 1 kmol/ m$^3$. Coolant water temperature is 300 °K.

Discuss the effect of variation of the overall heat transfer coefficient (UA) on the operation of CSTR.

Data given are:

\[ k = 4 \times 10^8 \exp(-7900/T), \ s^{-1} \]
\[ k' = 1 \times 10^{10} \exp(-9900/T), \ s^{-1} \]
\[ (\rho C_p) = 800 \text{ kcal/m}^3, \ \Delta T_{ad} = 100 \text{ °K} \]

**OR**

(a') Explain that the Van Heerden’s criterion of slope is necessary but not sufficient condition for the stable operation of an exothermic irreversible reaction in a CSTR.

(b) Draw conversion and temperature profiles for an exothermic irreversible reaction in an externally cooled reactor for various heat exchange capacities. What do you mean by adiabatic temperature rise of a reaction mixture on complete conversion of a reactant?

Contd... 4.
[c] Show the effect of variation of inlet reactor temperature and heat exchange area on the plots of \( Q(r) \) versus \( T \). What are the assumptions used by Berkelew's for approximate determination of \( T_{\text{max}} \)?

4(a) The catalytic decomposition of reactant \( A \rightarrow R \) is studied in a packed bed reactor filled with 2.4 mm pellets and using a very high recycle rate of product gases (assume mixed flow). The results of a long-time run and additional data are given below:

\[
\begin{array}{lcccc}
 t, \text{ hr} & 0, & 2, & 4, & 6 \\
 X_A & 0.75, & 0.64, & 0.52, & 0.39 \\
\end{array}
\]

Data given are:
\[ D_c = 5 \times 10^{-10} \text{ m}^3/\text{m cat.s}, \text{ density of the catalyst pellet} = 1500 \text{ kg/m}^3 \text{ cat}, \]
\[ \tau' = 4000 \text{ kg.s/m}^3 \]

Find the kinetics of reaction and deactivation, both in the diffusion free and in the strong pore diffusion resistance regime.

4(b) Explain the effect of catalyst deactivation on selectivity of parallel reactions. Explain the integral method for determining the order of deactivation.

4(c) What are the applications of Trickle bed reactors in Petroleum industry? Develop the rate equation for a first order reaction in a slurry reactor. How the different limiting resistances can be found out? What is the effect of particle size on controlling resistance?

**OR**

4(c') The first order isomerisation is being carried out isothermally in a batch reactor on a catalyst that is decaying as a result of aging. Derive an equation to predict the conversion as a function of time.
Answer all the questions.
Draw flowsheets by pencil and scale only
Write process conditions, description and reactions for all flowsheets except when asked to draw flowsheet only.

1(a) Draw flowsheet and explain semi-regenerative reformer, its catalyst regeneration parameters and types of catalysts that can be used for aromatic petrochemical production. [06]

1(b) Draw and explain steam cracking flowsheet for production of petrochemicals. Compare Gas versus Liquid Feedstock for steam cracking. [09]

2(a) Draw only flowsheet for the production of C1 petrochemical, Methanol. [04]

OR

2(a') Draw only flowsheet for the production of C1 petrochemical, Formaldehyde [04]

2(b) Explain why pure formaldehyde is not produced in formaldehyde production from methanol? Explain Oligomerization with example. [04]

2(c) Draw flowsheet and explain production of C2 petrochemical, Ethanol; by esterification and hydrolysis. [07]

OR

2(c') Draw flowsheet and explain production of C2 petrochemical, Ethylene oxide. [07]

3(a) Draw flowsheet and explain production of C3 petrochemical, Isopropanol. [08]

OR

3(a') Draw flowsheet and explain production of C3 petrochemical, Acrylonitrile. [08]

3(b) Draw block diagram of C4 petrochemical production. [07]

4(a) Draw flowsheet and explain production of BTX petrochemical, Phenol; by chlorination. [08]

OR

4(a') Draw flowsheet and explain production of BTX petrochemical, Maleic Anhydride. [08]

4(b) Explain direct and indirect liquefaction of coal. Draw various types of Coal-to-Liquid (CTL) gasifiers. [07]
Q.No. | Question | M.M.
--- | --- | ---
1(a) | Differentiate between; (i) Cis and Trans polymers. (ii) Linear, branched and network polymer structures. (iii) Degradation and De-polymerization of polymers. | [7.5] 
1(b) | Why polymers are viscoelastic in nature? Explain the phenomenon of stress relaxation and creep for polymers. | [7.5] 
1(b') | Write down the names of following crystallographic planes along with the basis. | [7.5] 
2(a) | In a DSC test for isotactic polypropylene (iPP) polymer was heated at the rate of 10 \(\frac{^\circ C}{min}\). The area under the melting peak has area of 25 \(\frac{Watt.\cdot ^\circ C}{g}\). Calculate the % crystallinity of isotactic polypropylene molded parts. Given: \(\Delta H_f = 207 \frac{L}{g}\), for 100% crystalline iPP | [7.5] 

Conld... 2.
2(b) Explain the construction and working principle of Differential Scanning Calorimeter (DSC).

OR

2(b') How dynamic loading is different that static loading? DMA plot of a polymer is given as under, read the value of Tg and Tm from the plots.

![DMA plot](image)

3(a) Briefly mention the manufacturing process of carbon fibre. Also discuss the merits and demerits of carbon fibre over glass fiber.

3(b) Consider a SMC designated as SMC – R45 containing E-glass fibers in a thermosetting matrix. The following data are known:

<table>
<thead>
<tr>
<th>E-glass Fiber</th>
<th>Polyester matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_t = 68.9$ GPa</td>
<td>$E_m = 3.45$ GPa</td>
</tr>
<tr>
<td>$\rho_t = 2540$ Kg/m$^3$</td>
<td>$\rho_m = 1100$ Kg/m$^3$</td>
</tr>
<tr>
<td>$l_t = 15.0$ mm</td>
<td></td>
</tr>
<tr>
<td>$d_t = 1.5$ mm</td>
<td></td>
</tr>
</tbody>
</table>

Calculate the tensile modulus, shear modulus and Possion’s ratio for the composite.

OR

3(b') A composite of carbon fiber and PEEK has carbon fiber 45% by weight. Find out the density and modulus of composite material. The properties of fiber and matrix is
given as under:

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (kg/m³)</th>
<th>Tensile strength (GN/m²)</th>
<th>Modulus (GN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEK</td>
<td>1300</td>
<td>0.058</td>
<td>3.8</td>
</tr>
<tr>
<td>Carbon Fiber</td>
<td>1800</td>
<td>2.1</td>
<td>400</td>
</tr>
</tbody>
</table>

4(a) Why the estimation of shear modulus in plane 1-2 ($G_{12}$) from stress strain curve in non PMC (i.e $\sigma_x$ vs. $\varepsilon_x$) yields over estimated result? Also describe the correct way of estimating $G_{12}$.

4(b) What is critical fiber length? Drive the expression for longitudinal tensile strength for discontinuous fiber.

**OR**

4(b'). Differentiate between the followings with the help of examples and/or equations:

(i). Orthotropic and isotropic materials.

(ii). Specially Orthotropic lamina and generally orthotropic lamina.

(iii). Compliance matrix and Reduced transformed compliance matrix.
2017-18
M.TECH. WINTER SEMESTER EXAMINATION
(PETROLEUM PROCESSING AND PETROCHEMICAL ENGINEERING)
GAS PROCESSING
PK-608
Credits: 04

Maximum Marks: 60
Duration: Two Hours.

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q No 1 Attempt all questions. Each question have equal marks. 4x3.0 = 12.0
(a) Mention merits and demerits of vertical separator.

   OR

(a') What do you mean by LTX unit? What is the limitation of LTX unit with reference to the material of construction?

(b) List the parameters and their effects on the water content of natural gas.
(c) Write down the structural formula for gas hydrates types of I,II & H
(d) Write down the criteria for selection of sweetening processes.

Q No 2 Attempt all questions. Each question have equal marks. 4x5.0 = 20.0
(a) Write a short note on the development of natural gas industry in India.

   OR

(a') Discuss the development of global natural gas industry.

(b) What is the primary and secondary separation phenomenon in separator? Find out the terminal velocity of liquid droplets fall in the gas under gravitational force.
(c) Explain hydrate phase behavior with the help of neat sketch.

   OR

(c') Compare the chemical addition of methanol and glycol for preventing the hydrate formation on the basis of following parameters

... contd... 2.
1. Temperature
2. Injection techniques
3. Potential downstream problem
4. Economics
5. Existing hydrates

(d) Write down names and structure of ethanol amines used for sweetening processes of natural gas.

OR

(d') What is the limit of acid gas in natural gas? Discuss the reason for removal of H$_2$S and CO$_2$ from natural gas

Q No 3 Attempts all questions. Each question have equal marks. 4x7.0 =28.0

(a) A separator, to be operated at 2000 psia is required to handle a wellstream with gas flow rate 9 MMscfd at a GLR = 60 bbl/MMscf. Determine the separator size required for:

- A vertical separator
- A horizontal single tube separator

Assume a liquid (oil+ water) density of 60 lbm/ft$^3$, ideal gas with gravity = 0.8, an operating temperature equal to 110 °F, a retention time t = 5 min and 1/2 full of liquid conditions.

Assuming Z = 1 and R 10.73

(b) Define dew point and dew point depression. Estimate the water content of natural gas at 100 °F and 1000 psia using (1) Robinson et al method & (2) Campbell’s method. The gas composition is as follows: CH$_4$ = 80.0%, C$_2$H$_6$ = 5.0%, C$_3$H$_8$ = 1.5%, nC$_4$H$_{10}$ = 0.5%, CO$_2$ = 2.5%, H$_2$S = 8.5%.

OR

(b') Name atleast 03 methods for predicting hydrate formation. For the gas with composition given below, find the hydrate forming temperature corresponding to a pressure of 6000 psia by McLeod Campbell method.

<table>
<thead>
<tr>
<th>Comp</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>i-C4</th>
<th>n-C4</th>
<th>C5+</th>
<th>CO2</th>
<th>H2S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yi</td>
<td>0.810</td>
<td>0.050</td>
<td>0.025</td>
<td>0.015</td>
<td>0.010</td>
<td>0.015</td>
<td>0.025</td>
<td>0.050</td>
</tr>
</tbody>
</table>
The K values is given as follows:

<table>
<thead>
<tr>
<th>Pressure</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>i-C4</th>
<th>n-C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td>10933</td>
<td>20806</td>
<td>28382</td>
<td>30696</td>
<td>17340</td>
</tr>
<tr>
<td>7000</td>
<td>18096</td>
<td>20848</td>
<td>28709</td>
<td>30913</td>
<td>17358</td>
</tr>
</tbody>
</table>

(c) What are the advantages of glycol dehydration over other dehydration processes? Discuss the glycol dehydration process with the help of neat sketch.

(d) Explain in brief different categories of sweetening processes with one industrial example. Also Discuss the water wash process with the help of flow diagram.
Figure 2. Effective water content of saturated CO₂ in natural gas mixtures (Campbell, 1976).

Figure 3. Effective water content of saturated H₂S in natural gas mixtures (Campbell, 1976).