Maximum Marks: 60
Credits: 04
Duration: Three Hours

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

Q.No. | Question | M.M.
--- | --- | ---
1(a) | Develop a steady state model for Isothermal CSTR (second order reaction). Also determine how one can find optimum values of dependent variables. | 05 |

OR

1(a') | A Stirred Tank Blending Process is shown in figure 1. Develop a dynamic model of the blending process assuming perfect mixing and constant density. Analyze the degree of freedom. Is this set of equation linear or nonlinear.

![Figure 1](image)

1(b) | Two liquid storage systems are shown in Figure 2. Each tank is 4 feet in diameter. For System I, the valve acts as a linear resistance with the flow-head relation \( q = 8.33h \), where \( q \) is in gal/min and \( h \) is in feet. For System II, variations in liquid level \( h \) do not affect exit flow rate \( q \). Suppose that each system is initially at steady state with \( h = 6 \text{ ft} \) and \( q_i = 50 \text{ gal/min} \) and that at time \( t = 0 \) the inlet flow rate suddenly

Contd…..2.
changes from 50 to 70 gal/min. For each system, determine the following:

(a) The transfer function $H'(s)/Q_i'(s)$ where the prime denote the deviation variables.

(b) The Transient response $h(t)$

Figure 2

2(a) A stirred tank reactor has an internal cooling coil to remove heat liberated in the reaction. A proportional controller is used to regulate coolant flow rate so as to keep the reactor temperature reasonably constant. The controller has been designed so that the controlled reactor exhibits typical underdamped second-order response characteristics when it is disturbed, either by feed flow rate or by coolant temperature changes.

(i) The feed flowrate to the reactor changes suddenly from 0.5 to 0.7 kg/s, and the temperature of the reactor content initially at 100°C, changes eventually to 105°C. What is the gain of the transfer function that relates changes in the reactor temperature to changes in feed flow rate?

(ii) The operator notes that the resulting response is slightly oscillatory with maxima estimated to be 105.5 and 105°C occurring at times 1000 and 3090 sec after the change is initiated. What is the complete process transfer function?

(iii) Predict rise time, $t_r$.

2(b) Why Controller Tuning is necessary. What are the various techniques for controller tuning. Describe On-Line Controller Tuning Method with its limitations.

OR

Contd.....3.
2(b') Consider a feed back control system given in figure 3 below with the following transfer functions:

\[ G_c = K_c, \quad G_v = 1/(2s + 1), \quad G_p = G_d = 1/(5s + 1) \text{ and } G_m = 1/(s + 1). \]

Find the values of controller gain \( K_c \) that make the feedback control system stable.

![Figure 3](image)

3(a) 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 \( K_{cu} = 7.88 \text{ and } P_u = 11.66 \))

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

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

**OR**

3(a') A process has the transfer function, \( G(s) = 2e^{-0.2s}/(s+1) \). Compare the PI controller settings for Direct Synthesis Method with \( \tau_c = 0.2 \text{ and } 1.0 \)

3(b) Describe with neat diagram any two of the following:

(a) Override Control

(b) Feed Forward Control

(c) Adaptive Control

(d) Cascade Control

4(a) Explain in simple physical terms how can you convert a continuous signal to discrete time signal and vice versa? Describe with the help of mathematical equation the ideal impulse sampler.
4(b) Develop a discrete time transfer function of a
   (i) PID Controller
   (ii) Zero order Hold plus Pure Integrator

4(c) The first order digital filter with Input-Output relationship given as
    \[ y_n = (1 - a) y_{n-1} + a x_n \]
where \( x_n \) is discrete time input to the filtering algorithm
\( y_n \) is discrete time output from filter
Find the discrete time transfer function of the filter.
Answer all the questions. Assume suitable data if missing. Notations used have their usual meaning.

Q.No. 1(a) The first order reaction \[ A \rightarrow B \] with \( k = 0.8/\text{min} \) is carried out in a real reactor with the following RTD function.

For \( 2\tau \geq t \geq 0 \) then \( E(t) = \sqrt{\tau^2 - (t-\tau)} \min^{-1} \) (hemi circle)
For \( t > 2\tau \) then \( E(t) = 0 \)
What is the mean residence time and variance?

OR

1(a') Show that the conversion predicted by tanks in series model is equal to the conversion predicted by maximum mixedness model for a first order reaction. How dispersion does affect fractional conversion in a reactor?
Develop the procedure by conducting a step tracer input experiment in a real CSTR [6] when it is modelled using dead-space and bypass arrangement. Evaluate the model parameters.

2(a) Develop the design equation and give the mass transfer correlation for parallel -plate reactors (monoliths), which are used as catalytic afterburners on automobiles. Show graphically the regions of mass transfer limited and reaction limited conditions.

2(b) A first order heterogeneous irreversible reaction was carried out over two different sized pellets. The pellets were contained in a basket reactor that was operated at sufficiently high rotation speeds that external mass transfer resistance was negligible. The results of two runs made under identical conditions are given below:

<table>
<thead>
<tr>
<th>Run</th>
<th>Measured rate (mol/g cat.s)*10^5</th>
<th>Pellet radius, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td>3.0</td>
<td>0.01</td>
</tr>
<tr>
<td>Run 2</td>
<td>15.0</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Calculate the Thiele modulus and effectiveness factor for each pellet. How small should the pellets be made to eliminate virtually all internal diffusion resistance?

OR

2(b') In a fixed bed catalytic reactor having first order, vapour phase decomposition of reactant A is carried out by using spherical catalyst particles having diameter 2.5 mm. The Effective mass diffusivity is

\[ D_e = 5.4 \times 10^{-5} \text{ m}^2/\text{hr. m catalyst, } K_{\text{eff}} = 1.75 \text{ kJ/ hr. m cat. A, } K_g = 325 \text{ m}^3/\text{hr. m}^2 \text{ cat., } h = 178 \text{ kJ/ hr. m cat. A.} \]

The catalytic reaction is exothermic. Heat of reaction (ΔHr) is = -175 kJ/mol A.

Concentration of reactant A in gas stream is 25 kg mol/m^3 at 340 °C and 1 atm. pressure. The observed rate of catalytic reaction \(-r_A = 1.6 \times 10^5 \text{ mol/hr m}^3 \text{ cat.} \)

Determine (i) whether the catalytic reaction rate is influenced by the gas film resistance?

(ii) Whether the catalytic reaction is strongly influenced by pore diffusion?

(iii) How much is the temperature variation within the catalyst particle and across the gas film?

2(e) Explain how true and the apparent reaction order, and activation energy are related when internal diffusion limitations are present.

Contd...3.
3(a) Discuss the ignition and extinction behaviour of an adiabatic CSTR with the help of conversion versus temperature plot. Explain that not all the multiple steady states are stable.

OR

3(a') What are the remedies commonly used to avoid hot spots in a tubular reactor? Discuss the effect of operating variables namely $T_a$ or $T_w$, $C_{Ao}$, and $v$ on the operation of a non-isothermal CSTR.

3(b) Explain the significance of $N_{ad}$ and $N_w$, which account for heat generation and cooling capacity respectively.

3(c) Explain graphically how maximum temperature rise $T_{max}$ can be controlled below any prescribed value in a tubular reactor?

4(a) What are the different types of catalyst deactivation? Explain them with the help of examples. Discuss how the temperature should be increased with time to maintain constant conversion in a packed bed reactor?

4(b) Discuss the effect of particle size and effect of gas absorption on the rate of reaction in a slurry reactor. List the algorithm to determine reaction limiting step. Methyl linoleate is to be converted to methyl oleate in a 2 m$^3$ slurry reactor. The molar feed rate of Methyl linoleate to the reactor is 0.7 kmol/min. The partial pressure of H2 is 6 atm and the reactor is considered to be well mixed. Calculate the catalyst charge necessary to achieve 30% conversion for a 60 micron meter particle size. Data: $n_e = 0.08$ min, $r_{cat} = 0.28$ min.kg/m$^3$, Solubility of hydrogen (kmol/m$^3$) = 0.014.

OR

4(b') In an automobile catalytic converter, CO and HC present in the exhaust gases are oxidized. Unfortunately the effectiveness of these units decreases with time. From the reported data on HC conversion shown below, develop an expression to represent the deactivation rate of the catalyst.

<table>
<thead>
<tr>
<th>Time, hr</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_{HC}$</td>
<td>0.57</td>
<td>0.53</td>
<td>0.52</td>
<td>0.50</td>
<td>0.48</td>
<td>0.45</td>
<td>0.43</td>
<td>0.41</td>
</tr>
<tr>
<td>Q.No.</td>
<td>Question</td>
<td>M.M.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1(a)</td>
<td>Write your views on Naphtha and Natural Gas as a feedstock for a petrochemical complex in India and also write the names, location and feedstock of existing Naphtha / Gas crackers in India.</td>
<td>[05]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1(b)</td>
<td>Classify catalytic Reforming process for the production of Aromatics. Discuss advantages of bimetallic and multimetallic Catalyst over monometallic Catalyst. Describe Reforming process with the help of a suitable process flow sheet and reactions involved.</td>
<td>[10]</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

OR

1(b') Describe Steam cracking process with the help of a suitable process flow sheet. Highlight important role of Steam in the process. Why the product gases from Naphtha and C₂-C₄ saturates Steam cracker processed separately before mixing them and sending them to the compressor and why specifically the gases are compressed to 35 atm? | [10] |

Contd.....2.
2(a) Draw a process flow sheet for the production of Formaldehyde from Synthesis Gas. Explain why light end stripper is used after absorber and suggest why pure Formaldehyde is not produced in the process? From engineering perspective, what is the most difficult part in the process flow sheet?

OR

2(a') Draw a process flow sheet for the production of Ethanolamines from Ethylene. Explain why Ethylene and air are separately compressed and why a compressor is used before the stripper? Why Ammonia + water needs to be separated from the second tower i.e., water separation tower?

2(b) Explain why Ethylene dichloride is dried before entering the cracking furnace and cold Ethylene dichloride quenching is carried out in production of Vinyl chloride from Ethylene dichloride?

2(e) Name different methods for the production of Industrial alcohols. Discuss the Major engineering problems associated with the Urea Plant and suggest some process modifications.

3(a) Discuss the process flow sheet for production of Acetone from Propylene through Isopropanol route. Why a partial condenser but not total condenser is used to separate C₃ from alcohol + ether? Is pure Isopropanol required as feedstock in the reactor?

3(b) How can one suppress polyalkylbenzene formation and in what way higher pressure in the product vapors from the reactor are beneficial for the depropanizer

Contd…..3.
unit in Cumene production from Propylene by alkylation process.

OR

3(b') Which process is used for the production of Acrylonitrile from Propylene? Why is Oxalic acid added in the Acrylonitrile purification column and whether a partial condenser is required in the Acetonitrile azeotropic column for the production of Acrylonitrile?

4(a) Draw a process flow sheet of Styrene by dehydrogenation of Ethyl Benzene. Why the Benzene is wet from the Benzene column? Why steam quenching but not water quenching is adopted?

4(b) Explain different process steps involved in the manufacturing of LAB and Caprolactum. Differentiate between FT and MTG process also write down the basic reactions involved.
Differentiate between;
(i). Cis and Trans polymers.
(ii). Linear, branched and network polymer structures.
(iii). Degradation and De-polymerization of polymers.
(iv). Condensation and step polymerization.

Why average molecular weight is needed in case of polymer? Explain the difference between $M_n$ and $M_w$, also describe the polydispersity curve in polymer.

OR

In a polymer fractionation experiment the following data was obtained;

<table>
<thead>
<tr>
<th>Mol. Wt. of fraction</th>
<th>100</th>
<th>200</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Chain</td>
<td>5</td>
<td>12</td>
<td>18</td>
<td>22</td>
<td>15</td>
<td>11</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

Calculate the number average and weight average molecular weight of polymer.
Also calculate the polydispersity index.

Write down the name of 4 polymers belonging to each of chain and step polymerization category. Differentiate between the step and chain polymerizations.
2(b) What do you mean by transition temperatures in polymers? Other than glass transition temperature explain any other transition temperature. Briefly explain the factors affecting glass transition temperature.

OR

2(b') Why average molecular weight is needed in case of polymer? Explain the difference between Mn and Mw, also describe the polydispersity curve in polymer.

3 A composite of carbon fiber and PEEK has carbon fiber 55% 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/m$^3$)</th>
<th>Tensile strength (GN/m$^2$)</th>
<th>Modulus (GN/m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEK</td>
<td>1350</td>
<td>0.06</td>
<td>4.0</td>
</tr>
<tr>
<td>Carbon Fiber</td>
<td>1780</td>
<td>2.2</td>
<td>390</td>
</tr>
</tbody>
</table>

OR

3' Consider a SMC designated as SMC - R65 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>$E_f = 68.9$ GPa</td>
<td>$E_m = 3.45$ GPa</td>
</tr>
<tr>
<td>$\rho_f = 2540$ Kg/m$^3$</td>
<td>$\rho_m = 1100$ Kg/m$^3$</td>
</tr>
<tr>
<td>$l_f = 25.0$ mm</td>
<td></td>
</tr>
<tr>
<td>$d_f = 2.5$ mm</td>
<td></td>
</tr>
</tbody>
</table>

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

4(a) What do you mean by biaxial strength of orthotropic lamina? Compare the maximum stress theory with maximum strain theory.

4(b) Drive the expression for critical volume fraction of fiber in a composite. Explain the role of fiber below critical volume fraction in composite.

OR

Contd....3.
4(b). In a X-ray diffraction experiment on isotactic polypropylene (iPP), the values of non-coplanar vectors and inter edge angles are as under:

\[ a = b = 11.03\text{Å}; \quad c = 6.49\text{Å}; \quad \alpha = \beta = 90^\circ; \quad \gamma = 120^\circ \]

Calculate the (20) value for plane (300) of β-iPP (hexagonal crystal structure).

**Given:**

\[
(d_{hkl})_{\text{hexagonal}} = \left(\frac{4}{3a^2} \left( h^2 + hk + k^2 \right) + \frac{l^2}{c^2}\right)^{\frac{1}{2}}
\]

\[ \lambda = 1.54\text{Å} \]
2015-16
M.TECH. WINTER SEMESTER EXAMINATION
(PETROLEUM PROCESSING AND PETROCHEMICAL ENGINEERING)

GAS PROCESSING
PK-608
Credits: 04

Maximum Marks: 60
Duration: Three Hours.

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

Q No 1
(a) Write a short note on the development of natural gas industry in India. 5.0

OR

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

(b) What do you mean by Gas processing? Explain in brief, with the help of block diagram. 5.0

(e) What are the important component of gravity separators? Explain with its significance. 5.0

Q No 2
(a) Define dew point and dew point depression. Also describe the parameter that affect the water content of natural gas. 5.0

(b) What is Gas Hydrate? Discuss the conditions that promote hydrate formation. 5.0

OR

(b') Discuss the types of gas hydrate and number of water molecules associated with each type of gas hydrate.

(e) 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

Contd......2
follows: \( \text{CH}_4 = 80.0\% \), \( \text{C}_2\text{H}_6 = 5.0\% \), \( \text{C}_3\text{H}_8 = 1.5\% \), \( \text{nC}_4\text{H}_{10} = 0.5\% \), \( \text{CO}_2 = 2.5\% \), \( \text{H}_2\text{S} = 8.5\% \).

**OR**

For the gas with composition given below, find the hydrate formation temperature corresponding to a pressure of 6000 psia by McLeod Campbell method.

<table>
<thead>
<tr>
<th>Comp</th>
<th>( \text{C}_1 )</th>
<th>( \text{C}_2 )</th>
<th>( \text{C}_3 )</th>
<th>( \text{i-C}_4 )</th>
<th>( \text{n-C}_4 )</th>
<th>( \text{C}_5+ )</th>
<th>( \text{CO}_2 )</th>
<th>( \text{H}_2\text{S} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{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 (psia)</th>
<th>( K_i ) Values for the McLeod Campbell Method for Predicting hydrate formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>6000</td>
<td>( \text{C}_1 )</td>
</tr>
<tr>
<td>7000</td>
<td>10933</td>
</tr>
</tbody>
</table>

Q No 3

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

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

(b) Discuss the desirable properties required in physical adsorption used in gas dehydration.

**OR**

(b') What are the problems encountered in the Glycol plant for dehydration of natural gas?

(c) Discuss in brief, Glycol dehydration process plant with the help of neat sketch.

Q No 4

(a) Write down the criteria for selection of sweetening processes.

**OR**

(a') Discuss the reasons for removal of acid gases from natural gas?

(b) Explain why Water Wash (Aquasorption) process is suitable before Amine Absorption process in sweetening process.
Discuss and compare the different amine solvent used in sweetening absorption process with the help of given table.

<table>
<thead>
<tr>
<th>Amine Type</th>
<th>Mol Wt</th>
<th>Vapor Pressure at 100 °F, mm Hg</th>
<th>Relative Capacity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEA</td>
<td>61.08</td>
<td>1.05</td>
<td>100</td>
</tr>
<tr>
<td>DEA</td>
<td>105.14</td>
<td>0.058</td>
<td>58</td>
</tr>
<tr>
<td>TEA</td>
<td>148.19</td>
<td>0.0063</td>
<td>41</td>
</tr>
<tr>
<td>DGA</td>
<td>105.14</td>
<td>0.160</td>
<td>58</td>
</tr>
<tr>
<td>DIPA</td>
<td>133.19</td>
<td>0.010</td>
<td>46</td>
</tr>
<tr>
<td>MDEA</td>
<td>119.17</td>
<td>0.0061</td>
<td>51</td>
</tr>
</tbody>
</table>

Calculated Water Content of Acid Gas Mixtures to 2000 psia

Fig 01: Robinson at al correlation for water content of sour gases in the 300-2,000 psia pressure range.
Fig: 02  Water contents of natural gases with corrections for salinity and gravity. (After McKetta and Wehe.)
Figure 3. Effective water content of saturated CO₂ in natural gas mixtures (Campbell, 1976).

Figure 4. Effective water content of saturated H₂S in natural gas mixtures (Campbell, 1976).