2016-17
B.TECH. (AUTUMN SEMESTER) EXAMINATION
BRANCH
COURSE TITLE: Process Dynamics and Control
COURSE CODE: PK 411

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) i. Explain the difference between manipulated variable and load variable, Partial self 
regulation and no self regulation.
ii. Draw the block diagram for water heater tank control, which has been provided 
with an inlet and an outlet for water to flow through the tank, with and without load.

1(b) Develop the transfer function for a single effect evaporator. Draw the block diagram 
for an evaporator. State all the assumptions made in the analysis. [5]

OR

1 (b) Given a system with the transfer function \( Y(s)/X(s) = \frac{(T_1s+1)}{(T_2s+1)} \). Find \( Y(t) \) if 
\( X(t) \) is a unit step function. If \( T_1/T_2=5 \), sketch \( Y(t) \) versus \( t/T_2 \). [5]

2(a) Determine \( Y(0) \), \( Y(0.6) \) and \( Y(\infty) \) if the transfer function \( Y(s) = \frac{1}{s} \frac{25(s+1)}{(s^2+2s+25)} \). [7]

OR

A process can be approximated by three first order lags in series with the time 
constants of 1,2 and 5 seconds, and a gain of 1 unit. Write the transfer function of the 
process and obtain \( Y(0) \) and \( Y(\infty) \). Discuss the significance of \( \tau \) and \( \xi \).

2(b) A water- filled manometer 60 cm long and 6.3 mm inside diameter glass tube is half 
filled and is subjected to a pressure differential of 3500 N/m2. Determine 
characteristic time and damping factor. Indicate if the manometer is suitable. 
Suggest design of the manometer considering the initial transient state. 
The density of water is 1000 kg/m3 and the viscosity is 1 m N-s/m2. [8]
3(a) In a PID controller, the error is increased linearly at a rate of 6°C/min. The sensitivity of the controller is 5, reset rate is 1 and derivative time is 0.5 min. Obtain the response of the controller and discuss its advantages over two modes controller.

(b) Obtain C/R for the control system as shown below:

In the above loop if the feedback signal is added with the set point in the comparator, then again obtain C/R.

OR

3' (b) Determine the stability for the open loop transfer function, \( K/(s^2+s+20 K) \).
What are the limitations of the Routh-Hurwitz criterion? Draw the Bode plot for a pure capacitive process and P controller.

4(a) What are the advantages of cascade control system over the conventional feedback control system? Will cascading help for a loop consisting of a PI controller, having integral time of 1/3, a first order final control element having gain and time constant of unity each, and a first order process having gain of unity and time constant of 2? The cascade will have a P controller and the final control element in the loop. When a slave (P with \( K_c = 4 \)) controller is cascaded with the final control element.

4(b) What is an auctioneering control system, and how would you use it for the regeneration of the catalyst?

OR

Contd...
4(b) Explain how you convert a continuous to a discrete time signal and vice versa. Discuss the mathematical basis for the reconstruction of continuous signals from their discrete–time values.

OR

4 (b) Develop the discrete time model of a second order process.
1(a) (i) Read the following story and answer the question that follow:

"A final year B.Tech. student was offered a job with a salary of ₹20,000 per month and he accepted the offer. Few days later he received another job offer from a second company with salary of ₹30,000 per month. The student consulted a teacher whether he should accept the new offer and break the promise made to the first company. The teacher was inclined to tell the student to stand by the commitment made to the first company. Several years later, another final year student received two job offers simultaneously: one with a salary of ₹25,000 per month and another with a salary of ₹35,000 per month. The student accepted the offer with the salary of ₹35,000 but later found that the company broke the promise of the offer because of downturn in its economy. Furthermore, the other job (with a salary of ₹25,000) offered by the other company was no longer available. The student reported this incident to the same teacher. From then onwards, the teacher started telling the students to look out for students' own interests, i.e., if they got a better offer after accepting an earlier offer, then break the promise on the first and take the second."

Was the teacher giving ethical advice? Explain.

(ii) Give three reasons to use a batch process and three reasons to use a continuous process.

OR

1(a') Discuss the factors to be considered for selecting location of chemical process plant?

1(b) The heat exchanger shown below is operating at condensing steam mode. Draw the portion of a P&ID showing how the steam side is controlled, including any auxiliary equipment. Show any other typical information included in a P&ID.
2(a) Discuss the cost components of fixed-capital investment (FCI) for a chemical plant. In your discussion include approximate cost of each component in percentage of FCI.

OR

2(a') Two separate discrete cash flow patterns are shown in table below. With interest compounded monthly at a rate of 10% per year, calculate the total amount of the cash flow, the present worth at zero time, and the future worth at 12 months for both the series of cash flows. Show that both of them have the same worth at a particular time.

<table>
<thead>
<tr>
<th>End of month</th>
<th>Cash Flow 1, ₹</th>
<th>Cash Flow 2, ₹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>800000</td>
<td>560000</td>
</tr>
<tr>
<td>2</td>
<td>800000</td>
<td>880000</td>
</tr>
<tr>
<td>3</td>
<td>800000</td>
<td>920000</td>
</tr>
<tr>
<td>4</td>
<td>800000</td>
<td>760000</td>
</tr>
<tr>
<td>5</td>
<td>800000</td>
<td>800000</td>
</tr>
<tr>
<td>6</td>
<td>800000</td>
<td>600000</td>
</tr>
<tr>
<td>7</td>
<td>800000</td>
<td>880000</td>
</tr>
<tr>
<td>8</td>
<td>800000</td>
<td>760000</td>
</tr>
<tr>
<td>9</td>
<td>800000</td>
<td>800000</td>
</tr>
<tr>
<td>10</td>
<td>800000</td>
<td>480000</td>
</tr>
<tr>
<td>11</td>
<td>800000</td>
<td>640000</td>
</tr>
<tr>
<td>12</td>
<td>800000</td>
<td>154432</td>
</tr>
</tbody>
</table>

2(b) In the design of a chemical plant, the following expenditures and revenues are estimated after the plant has achieved its desired production rate:

- Total capital Investment: ₹ 10,00,00,000
- Working Capital: ₹ 1,00,00,000
- Annual Sales: ₹ 7,50,00,000
- Annual Expenditures: ₹ 1,70,00,000

Assuming straight-line depreciation over a 10 year project analysis period, determine:

(i) The return on investment
(ii) The payback period

3 (i). Discuss general guidelines for separation process selection. In your discussion include the characteristics of separation processes and the exploitable property differences.

(ii). The figure in next page shows various temperature profiles developed in heat exchangers.

In each subplot mention the following:

A. Whether it is parallel or counter current flow.
B. Whether phase change is occurring in any stream
C. Physical change occurring in each stream (like: heating cooling, condensing, evaporating, etc.)

(You may work on the figure itself, then submit the page along with your answer book)
Figure

Various temperature profiles developed in heat exchangers for parallel or countercurrent flow, with one or two phases present (temperature $t_1$ and $T_1$ are the inlet temperatures for the hot and cold streams, respectively, and $t_2$ and $T_2$ are the exit temperatures for the hot and cold streams, respectively).
3' Reactor Combination by Graphical Method

The autocatalytic reaction \( A \rightarrow B \) has the isothermal rate versus conversion behaviour shown in the table below; the rate values are in \( \text{kg-mol/m}^3\cdot\text{s} \)

<table>
<thead>
<tr>
<th>(-r_A)</th>
<th>(X_A)</th>
<th>(-r_A)</th>
<th>(X_A)</th>
<th>(-r_A)</th>
<th>(X_A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6.03 \times 10^{-3})</td>
<td>0.00</td>
<td>(9.53 \times 10^{-3})</td>
<td>0.35</td>
<td>(1.56 \times 10^{-2})</td>
<td>0.70</td>
</tr>
<tr>
<td>(6.41 \times 10^{-3})</td>
<td>0.05</td>
<td>(1.02 \times 10^{-2})</td>
<td>0.40</td>
<td>(1.64 \times 10^{-2})</td>
<td>0.75</td>
</tr>
<tr>
<td>(6.82 \times 10^{-3})</td>
<td>0.10</td>
<td>(1.10 \times 10^{-2})</td>
<td>0.45</td>
<td>(1.69 \times 10^{-2})</td>
<td>0.80</td>
</tr>
<tr>
<td>(7.28 \times 10^{-3})</td>
<td>0.15</td>
<td>(1.18 \times 10^{-2})</td>
<td>0.50</td>
<td>(1.68 \times 10^{-2})</td>
<td>0.85</td>
</tr>
<tr>
<td>(7.77 \times 10^{-3})</td>
<td>0.20</td>
<td>(1.28 \times 10^{-2})</td>
<td>0.55</td>
<td>(1.51 \times 10^{-2})</td>
<td>0.90</td>
</tr>
<tr>
<td>(8.30 \times 10^{-3})</td>
<td>0.25</td>
<td>(1.37 \times 10^{-2})</td>
<td>0.60</td>
<td>(1.06 \times 10^{-2})</td>
<td>0.95</td>
</tr>
<tr>
<td>(8.89 \times 10^{-3})</td>
<td>0.30</td>
<td>(1.47 \times 10^{-2})</td>
<td>0.65</td>
<td>(2.88 \times 10^{-3})</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Use graphical methods to find the reactor volume required to produce a 96% conversion of \( A \) if the reactor type is: (i) CSTR; (ii) PFR. Which type of reactor has smaller reactor volume?

(i) Mark the information that you can obtain from the following diagrams. Why one diagram can be advantageous over the other?

![Composite diagram](image)

(ii) Briefly discuss the steps involved in qualitative design procedure for plantwide control.

Useful Expressions:

- \( P = F(1 + i)^{-N} \)
- \( P = F(1 + i/12)^{-j} \)
- \( P = F(1 + i/12)^{12-j} \)
- \( \dot{q} = m\dot{\lambda} \)
- \( \dot{q} = UA\Delta T \)
- \( \dot{q}(\text{reboiler}) = mC_p(\text{feed} - \text{top}) = \dot{q}(\text{condenser}) + mC_p(\text{bottom} - \text{top}) \)
- Heat capacity of water = 4.2 \( \text{kJ/kg-K} \)
Answer all the questions.

Q.No. Question

1(a) Differentiate between first generation, second generation and value added Petrochemicals. What are different processes within refinery which will help in integration of refinery and petrochemical complex? [05]

1(b) Why is vacuum distillation required for Maleic Anhydride refining? Discuss its production with the help of a process flow sheet. Explain why waste steam recovery boiler is kept before heat integrated exchanger from the vapor products perspective? [10]

OR

1(b') Why is the fluidized bed operated at a higher temperature in Pthalic anhydride production? Describe its production with suitable process flow sheet. How do switch condensers assist in generating the crude solid product in Pthalic anhydride production? [10]

2(a) Compare chemical properties of DMT and Terephthalic acid. Write down the principle of Witten process for the Production of DMT with the help of Chemical reactions; also discuss basic uses of DMT and Acrylic acid. [10]

OR

2(a') What is the predominant use of Terephthalic acid in India? Name different processes for its manufacturing and which process is famous for purification and reaction steps. Discuss its production by Amoco process with the help of process...
flow sheet, chemical reactions and suitable description.

2(b) Discuss important properties and applications of Methyl Methacrylate. Write the names of major producers of Methyl Methacrylate in India [05]

3(a) Why PVC requires less petroleum than many other polymers for its production? Discuss its production with the help of suitable process flow sheet. How it can be formulated as flexible, rigid, elastomeric and foamed compound? [09]

3(b) Discuss technological developments in the production of polyethylene from high pressure to low pressure process. Why ethylene conversion is kept upto 10-25% only and outlet temperature of reactor should not below 200°C during the production of LDPE by high pressure process? [06]

3(b') Although Polystyrene is an aromatic compound but it is used to make container for chemicals, solvents and fluid, why? What property allows it to be used as engineering plastics? Why it is not suitable for high temperature moulding? [06]

4(a) What are three important properties of Poly Carbonate that makes it as engineering Polymer of the choice? Described the production of ABS plastic with the help of process flow sheet. [10]

4(b) Write down the series of reactions involved in the synthesis of Caprolactum from Benzene and Ammonium Carbonate. [05]
B.TECH. (AUTUMN SEMESTER) EXAMINATION
PETROCHEMICAL ENGINEERING
POLYMER SCIENCE & TECHNOLOGY
PK-433

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.1 Answer any FIVE parts. Each part carries equal marks.

i. Which one among the followings is not a polymer; and why?
Wood, Hevea rubber, Bisphenol-A, polyethylene glycol, Silk, Urea formaldehyde, Cellulose

ii. Shoe sole has to be designed for Indian army personnel's deployed in Siachen. There the temperature may fall to -30°C during winter. Flexibility of sole is an important aspect. Please select the polymeric materials from following list and justify your selection.

<table>
<thead>
<tr>
<th>Polymers</th>
<th>Glass Transition Temp. (°C)</th>
<th>Melting Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Polyethylene (HDPE)</td>
<td>-111°C</td>
<td>146°C</td>
</tr>
<tr>
<td>ii. Polyvinyl Chloride (unplasticized)</td>
<td>80°C</td>
<td>170°C</td>
</tr>
<tr>
<td>iii. Nylon</td>
<td>47- 60°C</td>
<td>220</td>
</tr>
<tr>
<td>iv. Rubber</td>
<td>-70°C</td>
<td></td>
</tr>
</tbody>
</table>

iii. Differentiate between thixotropic and pseudoplastic polymers with the help of examples of each.

iv. The design of plasticizing single screw is given below in figure. Name the missing details 1 and 2 and explain briefly their importance and function.

[Diagram of single screw with missing details 1 and 2 marked]

Cont’d on 2
v. The DSC thermogram (heating-cooling combined) of an unknown polymer is given in figure below. Name all the peaks in figure.

![DSC thermogram diagram]

vi. Styrene can be polymerized with a peroxide initiator or in the presence of perchloric acid. In one case it follows the kinetics of Chain polymerization while in other if follows the kinetics of Step polymerization. Club the correct pair and differentiate between Chain and Step polymerization.

Q.No.2 Answer any THREE parts. Each part carries equal marks.

i. Calculate the solubility parameter (\(\delta\)) for poly(methyl methacrylate) by Smalls' method.

Data:

<table>
<thead>
<tr>
<th>Groups</th>
<th>-CH(_3)</th>
<th>-CH(_2)</th>
<th>&gt;C&lt;</th>
<th>-COO-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molar Attraction Constant (G)</td>
<td>438</td>
<td>272</td>
<td>-190</td>
<td>634</td>
</tr>
</tbody>
</table>

ii. In a rheological experiment the following data was obtained for a fluid;

<table>
<thead>
<tr>
<th>Strain rate (s(^{-1}))</th>
<th>0</th>
<th>100</th>
<th>1000</th>
<th>10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Stress (MPa)</td>
<td>354.8134</td>
<td>15488.166</td>
<td>1.02 x 10(^5)</td>
<td>6.76 x 10(^5)</td>
</tr>
</tbody>
</table>

(i). Calculate the power law index (\(n\)) and viscosity

(ii). Describe the type of fluid.

iii. Name the viscoelastic model represented by the series combination of dashpot and spring, as shown in figure below. Also calculate the relaxation time (\(\lambda\)) for this model.

![Viscoelastic model diagram]

\[\eta = 55 \text{ GPa.s} \quad E = 5.0 \text{ GPa}\]

iv. Explain with example the structural factors affecting the glass transition temperature (\(T_g\)) of
polymer.

Q.No.3 Answer any THREE parts. Each part carries equal marks.

i. Write down the W-R-Mooney equation for capillary rheometer. Explain the difference between apparent shear rate and true shear rate.

ii. Derive the following relationship for step polymerization reaction;
Rp = K.K3 [COOH]. [HA]. [OH]
Also explain the assumptions for above relation.

iii. Differentiate among (a). Extrusion Blow Molding (b). Injection Blow Molding (c). Stretch Blow Molding. Which technique will be used for the manufacture of PET bottles for carbonated softdrinks?

iv. Calculate the feed ratio (r) of Adipic acid (AA) and Hexamethylene diamine (HMD) that should be used to get polyamide 6.6 of molecular weight 15000 at p= 99.5 and 100% conversion.

Q.No.4 Answer any TWO parts. Each part carries equal marks.

i. Explain the Viscometeric plot for polymer. Also explain effect of various processing parameter over viscosity of polymer melt with the help of suitable curves.

ii. Explain the followings:
   (i). time delayed deformation/ recovery
   (ii). Instantaneous deformation/ recovery.
   (iii). Energy dissipation.

iii. Calculate the change in crystallinity of PET sample containing 0.5 % voids by volume. Sample density is 1.395 g/cc.
ρv = 1.455 g/cc and ρs = 1.335 g/cc

iv. Draw the neat and clean sketch of direct hydraulic injection molding machine. Lable its main parts. Also explain the complete injection molding cycle.