GUJARAT TECHNOLOGICAL UNIVERSITY

BE 7 SEMESTER – OLD PAPER – S22 TO S26 – QUESTION BANK

Subject Name & Code: Process Modelling, Simulation and Optimization - 3170513

Chapter 1: Introduction

Repeated Questions:

None identified.

Other Important Questions:

1. Applications of Modelling and Simulation:

- **Q.** Explain various applications of modelling and simulation. **(SUMMER 2022, 3 Marks)**

Chapter 2: Modelling Aspects

Repeated Questions:

1. Types and Classification of Models:

- **Q.** Differentiate between deterministic and stochastic models. **(U3, 3 Marks; WINTER 2022, 3 Marks)**
- **Q.** Give a detail classification of models. **(U3, 7 Marks; WINTER 2022, 7 Marks)**
- **Q.** Compare linear model and non linear model. **(U3, 3 Marks OR; WINTER 2022, 3 Marks OR; WINTER 2024; SUMMER 2025, 4 Marks; WINTER 2025, 4 Marks)**

2. Black Box Model:

- **Q.** Explain black box model. **(SUMMER 2025, 4 Marks OR; WINTER 2025, 4 Marks OR)**

Other Important Questions:

1. Black Box, White Box and Gray Box Models:

- **Q.** Define: black-box model, white box model, gray model. **(SUMMER 2026, 3 Marks)**
- **Q.** Explain white box model. **(SUMMER 2022, 4 Marks)**

2. Model Building:

- **Q.** Elaborate the process to build a model. **(SUMMER 2026, 3 Marks)**
- **Q.** Explain the importance of degree of freedom in model building. **(SUMMER 2022, 3 Marks OR)**

3. Curve Fitting (Numerical):

- **Q.** An oven is tested for heating and the following set of time and temperature data is collected. Fit the data to the equation, T = a + bt where a and b are constants. [Diagram required – refer to the original question paper] **(SUMMER 2026, 7 Marks)**

Chapter 3: Mathematical Modelling of Chemical Engineering Systems

Repeated Questions:

1. Uses of Mathematical Models:

- **Q.** Explain the uses of mathematical models. **(SUMMER 2022, 3 Marks; SUMMER 2025, 3 Marks; WINTER 2025, 3 Marks)**

2. Fundamental Laws:

- **Q.** Describe briefly the fundamental laws used in mathematical models of chemical engineering systems. / Explain the fundamental laws of physics and chemistry with their applications to simple chemical systems. / Briefly explain the fundamental laws used in model building of chemical engineering systems. **(U3, 4 Marks; WINTER 2022, 4 Marks; WINTER 2024; SUMMER 2025, 4 Marks; WINTER 2025, 4 Marks; SUMMER 2026, 4 Marks)**

3. Transport Equations:

- **Q.** Write a note on the transport equations used for modeling. **(U3, 4 Marks OR; WINTER 2022, 4 Marks OR)**

Other Important Questions:

None identified.

Chapter 4: Examples of Mathematical Models of Chemical Engineering Systems

Repeated Questions:

1. Batch Reactor Model:

- **Q.** Develop a batch reactor model. / Develop a model for batch reactor. State the assumptions clearly. **(U3, 4 Marks; SUMMER 2022, 7 Marks; WINTER 2022, 4 Marks; SUMMER 2026, 7 Marks OR)**

2. Tank Models (Numerical):

- **Q.** A tank contains 10 lit. of fresh water at time t = 0, brine having a concentration of 10 kg/m³ of salt is feed into the tank at a rate of 0.5 lit/min. The mixture is kept uniform by mixing. The output from the tank is 0.4 lit/min. Evaluate the volume of water in the tank when the concentration inside the tank is 25% of that of inlet. **(U3, 7 Marks; WINTER 2022, 7 Marks)**
- **Q.** A fluid of constant density ρ is pumped into a cone-shaped tank of total volume $H\pi R^2/3$. The flow out of the bottom of the tank is proportional to the square root of the height h of liquid in the tank. Derive the equations describing the system. [Diagram required – refer to the original question paper] **(SUMMER 2025, 7 Marks; WINTER 2025, 7 Marks)**

3. CSTR Models:

- **Q.** Benzene is nitrated in an isothermal CSTR in three sequential irreversible reactions: Benzene + HNO_3 → nitrobenzene + H_2O; Nitrobenzene + HNO_3 → dinitrobenzene + H_2O; Dinitrobenzene + HNO_3 → trinitrobenzene + H_2O. Assuming each reaction is linearly dependent on the concentrations of each reactant, derive a dynamic mathematical model of the system. There are two feed streams, one pure benzene and one concentrated nitric acid (98 wt %). Assume constant densities and complete miscibility. [Diagram required – refer to the original question paper] **(SUMMER 2025, 7 Marks OR; WINTER 2025, 7 Marks OR)**
- **Q.** Develop the equations for the series of isothermal, variable holdup CSTRs. List all the assumptions with their justifications. / Develop a model for a series of isothermal, variable hold-up CSTRs in which a first order reaction A → B is taking place. State the assumptions clearly. **(SUMMER 2022, 7 Marks; WINTER 2024, 7 Marks)**

4. Distillation Column Model:

- **Q.** Explain mathematical modelling of ideal binary distillation column. **(U3, 7 Marks OR; WINTER 2022, 7 Marks OR; SUMMER 2025, 7 Marks; WINTER 2025, 7 Marks)**

Other Important Questions:

1. Heated Tank and Mixing Tank Models:

- **Q.** Derive the model equations for two heated tanks. **(SUMMER 2026, 4 Marks)**
- **Q.** Develop a model for mixing tank. State the assumptions. **(SUMMER 2026, 7 Marks)**

2. Reactor Model with Series Reaction:

- **Q.** Develop a model for a batch reactor where a series reaction A → B → C takes place inside the reactor and B is the desirable product. The batch reactor consists of a jacket for heating and cooling purposes. Make other suitable assumptions wherever necessary. **(WINTER 2024, 7 Marks)**

3. Solvent Extraction Model:

- **Q.** Derive relation for solute to be extracted in a steady state two stages solvent extraction unit. Using this relation develop relation for 'N' stages. **(WINTER 2024 OR)**

Chapter 5: Chemical Process Plant Simulation

Repeated Questions:

1. Process Simulators and Simulation Modes:

- **Q.** Describe any one chemical process simulator and its salient features. **(U3, 3 Marks; WINTER 2022, 7 Marks OR; SUMMER 2025, 4 Marks; WINTER 2025, 4 Marks)**
- **Q.** List the various professional simulators used in chemical engineering. / List process simulators used in chemical engineering. Discuss the common features of process simulators. **(WINTER 2024 OR; SUMMER 2026, 3 Marks)**
- **Q.** Explain equation oriented mode in simulation. **(SUMMER 2025, 3 Marks; WINTER 2025, 3 Marks)**
- **Q.** Differentiate between steady state and dynamic simulation. **(SUMMER 2022, 4 Marks OR; WINTER 2024; SUMMER 2026, 3 Marks)**
- **Q.** Differentiate between design mode and analysis mode in process simulation with a diagram. [Diagram required – refer to the original question paper] **(WINTER 2024, 4 Marks; SUMMER 2026, 4 Marks)**

2. Solution Approaches:

- **Q.** Explain equation solving approach in brief. / Explain equation solving approach with an example. **(SUMMER 2022, 3 Marks; SUMMER 2026, 4 Marks)**
- **Q.** Differentiate sequential modular approach and simultaneous modular approach. **(U3, 3 Marks OR; WINTER 2022, 3 Marks OR)**
- **Q.** List the structural components of general purpose sequential modular program. **(SUMMER 2025, 7 Marks OR; WINTER 2025, 7 Marks OR)**

3. Decomposition, Tearing and Graphs:

- **Q.** Write short note on decomposition of networks. **(U3, 4 Marks OR; SUMMER 2022, 4 Marks; WINTER 2022, 4 Marks OR; SUMMER 2025, 4 Marks; WINTER 2025, 4 Marks; SUMMER 2026, 3 Marks OR)**
- **Q.** Write about partition and tearing applied to process flow sheeting. Explain any tearing algorithm with a flowchart. Write the steps clearly. / Discuss the salient features of basic tearing algorithm with a flowchart. / Explain the features of Basic Tearing Algorithm. [Diagram required – refer to the original question paper] **(SUMMER 2022, 7 Marks OR; WINTER 2024, 4 Marks; SUMMER 2026, 7 Marks OR)**
- **Q.** Explain digraph and signal flow graph, with diagram. [Diagram required – refer to the original question paper] **(SUMMER 2025, 3 Marks OR; WINTER 2025, 3 Marks OR)**

Other Important Questions:

1. Solution Approaches:

- **Q.** What is sequential modular approach in simulation? Explain the step with diagram. [Diagram required – refer to the original question paper] **(SUMMER 2022, 7 Marks OR)**

Chapter 6: Basic Concepts of Optimization

Repeated Questions:

1. Optimization Steps and Obstacles:

- **Q.** Explain the steps for solving optimization problems. Enlist the general obstacles faced while solving optimization problems. / List the six general steps for the analysis and solution of optimization problem. / Describe the major obstacles to optimization problem. / Write the steps for solving optimization problems. Also list the common obstacles faced while solve optimization problems. **(SUMMER 2022, 7 Marks; SUMMER 2022, 4 Marks; WINTER 2024; SUMMER 2026, 7 Marks)**

2. Basic Definitions:

- **Q.** Define: feasible region, global minimum, convex region. **(U3, 3 Marks; WINTER 2022, 3 Marks)**

3. Quadratic Approximation (Numerical):

- **Q.** Find the quadratic approximation to w at the point (1, 0, 2). $w = x \sin(y) + y^2 + xyz + z$. **(SUMMER 2025, 7 Marks OR; WINTER 2025, 7 Marks OR)**

Other Important Questions:

1. Convexity, Concavity and Definiteness:

- **Q.** Determine whether the function is convex or concave. $f(x) = 2x_1^2 - 3x_1x_2 + 2x_2^2$. **(WINTER 2024)**
- **Q.** Explain concavity with examples. **(WINTER 2022, 3 Marks)**
- **Q.** Determine positive-definiteness of a function $f(x) = 2x_1^2 - 3x_1x_2 + 2x_2^2$. **(SUMMER 2022, 4 Marks OR)**

2. Basic Terms and Optimality Conditions:

- **Q.** Explain the meaning of following terms for optimization: Feasible solution, feasible region, optimal solution. **(SUMMER 2022, 3 Marks)**
- **Q.** Explain the necessary and sufficient conditions for an extremum of an unconstrained function. **(SUMMER 2022, 4 Marks)**

Chapter 7: Optimization of Unconstrained Functions

Repeated Questions:

1. Unconstrained Multivariable Search Methods (Theory):

- **Q.** Classify the methods to solve unconstrained multivariable problems. **(U3, 3 Marks; WINTER 2022, 3 Marks; SUMMER 2025, 3 Marks; WINTER 2025, 3 Marks)**
- **Q.** Explain Random search method and its significance. / Explain Random search and grid search method for unconstrained multivariable optimization. / Explain Random search method for multivariable optimization and its importance. **(U3, 4 Marks; WINTER 2022, 4 Marks; WINTER 2024; SUMMER 2025, 3 Marks; WINTER 2025, 3 Marks; SUMMER 2026, 3 Marks OR)**

2. One-Dimensional Search Methods (Theory):

- **Q.** Draw the flow chart for implementing Fibonacci method. [Diagram required – refer to the original question paper] **(SUMMER 2025, 4 Marks; WINTER 2025, 4 Marks)**

3. Unconstrained Optimization (Numerical):

- **Q.** Using Hooke-Jeeves method minimize $Z = f(x, y) = (x^2 + y - 11)^2 + (x + y^2 - 7)^2$. Take initial point $x^{(0)} = (x^{(0)}, y^{(0)}) = (0, 0)$ and increment vector $\Delta = (0.5, 0.5)$. **(SUMMER 2025, 7 Marks; WINTER 2025, 7 Marks)**
- **Q.** Minimize $f(x) = x^2 - x$ by Newton's method and Secant method. Use the starting point in the range of −3 to +3. Compare the methods. / Minimize the quadratic function $f = x^2 - x$ by Newton method. Use the range −3 to +3. / Minimize the quadratic function $f(x) = x^2 - x$ using finite difference Newton method start with $x = 3$ and $h = 0.001$. **(SUMMER 2022, 3 Marks OR; WINTER 2024 OR; SUMMER 2026, 4 Marks)**
- **Q.** A box with a square base and open top is to hold 1000 cm^3. Find the dimensions that require the least material (assume uniform thickness of material) to construct the box. / A box with a square base and open top is required to construct having volume of 1000 cm^3. Find the dimensions that require the least material (assume uniform thickness of material) to construct the box. **(SUMMER 2022, 4 Marks; WINTER 2024)**
- **Q.** Find the minimum of the function $f(x) = 0.65 - 0.75/(1 + x^2) - 0.65x \tan^{-1}(1/x)$. Use Quasi Newton method with the starting point $x_1 = 0.1$ and step size $\Delta x = 0.01$ in central difference formula; use $\varepsilon = 0.01$ for checking convergence. **(SUMMER 2025, 7 Marks; WINTER 2025, 7 Marks)**

Other Important Questions:

1. Search Methods (Theory):

- **Q.** Show the advantages and disadvantages of region elimination methods. **(WINTER 2024)**
- **Q.** Explain simplex search method. **(SUMMER 2022, 3 Marks OR)**
- **Q.** Explain in brief how one-dimensional search is applied in a multidimensional problem. **(SUMMER 2022, 7 Marks OR)**

2. Unconstrained Optimization (Numerical):

- **Q.** Minimize the function $f(x) = x^2 + 54/x$ between the interval [2, 5] using (i) Bisection search method, (ii) Golden section search method. Compare the methods. **(SUMMER 2026, 7 Marks)**
- **Q.** Minimize the function $f = 4x^3 + x^2 - 7x + 14$ in the interval 0 and 1 using (i) Bisection method and (ii) Golden section method. Compare the methods. **(WINTER 2024, 7 Marks OR)**
- **Q.** Minimize function $f(x) = x^4 - x + 1$ using Newton's method for starting point of $x = 3$; show five iterations. **(SUMMER 2022, 7 Marks)**
- **Q.** Minimize the function $f(x) = 8x_1^2 + 5x_2^2 + 4x_1x_2$ using Newton's method. Take starting point $X_o = [10, 10]$. **(SUMMER 2026, 4 Marks OR)**

- **Q.** Minimize the function $f = 4x_1^2 + x_2^2 - 2x_1x_2$ using Newton's method. Take starting point [1, 1]. **(WINTER 2024 OR)**
- **Q.** Find the extreme points of the function and classify them. $f(x) = x_1^3 + x_2^3 + 2x_1^2 + 4x_2^2 + 6$. **(SUMMER 2026, 4 Marks OR)**
- **Q.** Find the extreme points of the function and classify them. $f(x) = x_1^2 + x_2^2 + 2x_1^2 + 4x_2^2 + 6$. **(WINTER 2024, 7 Marks OR)**
- **Q.** Find the values of x and z (both > 0) that maximize the function: $U = -x^2 + 10x + xz - z^2 + 8z + 2$. **(SUMMER 2026, 3 Marks)**
- **Q.** A closed cylindrical vessel can hold 20π m³ of liquid. The material for the top and bottom costs \$10 per m² and material for the side costs \$8 per m². Find the radius and height of the most economical vessel. **(SUMMER 2026, 7 Marks OR)**

Chapter 8: Linear Programming (LP) and Applications

Repeated Questions:

1. Linear Programming Theory:

- **Q.** Explain Simplex algorithm for linear programming. **(U3, 4 Marks; WINTER 2022, 4 Marks)**
- **Q.** Explain primal-dual relationship in LP Problem. **(SUMMER 2025, 3 Marks OR; WINTER 2025, 3 Marks OR)**
- **Q.** What is a linear programming problem? State the linear programming in standard form and write down its application in chemical industries. **(U3, 7 Marks OR; WINTER 2022, 7 Marks OR)**

2. Simplex Method (Numerical):

- **Q.** Use the simplex method to find the maximum value of $Z = 2x_1 - x_2 + 2x_3$ subject to the given constraints and $x_1, x_2, x_3 \geq 0$. [Data truncated in source – refer to the original question paper] **(U3, 7 Marks; WINTER 2022, 7 Marks - U3 gives equality constraints; W22 gives inequality constraints; refer to original papers for exact constraint signs)**
- **Q.** A manufacturer produces three types of plastic fixtures. The time required for molding, trimming, and packaging is given in Table. (Times are given in hours per dozen fixtures). Use simplex method and find how many dozen of each type of fixture should be produced to obtain a maximum profit? [Diagram required – refer to the original question paper] **(SUMMER 2025, 7 Marks; WINTER 2025, 7 Marks)**

Other Important Questions:

1. Simplex Method (Numerical):

- **Q.** Solve the following Linear Programming Problem by Simplex method. Maximize $Z = 5x_1 + 3x_2$ subject to the given constraints and $x_1, x_2 \geq 0$. [Data truncated in source – refer to the original question paper] **(SUMMER 2026, 7 Marks OR)**
- **Q.** Solve the following linear programming problem using simplex method. Maximize $Z = 6x_1 + 5x_2$ subject to $x_1 + x_2 \leq 5$, $3x_1 + 2x_2 \leq 12$, $x_1, x_2 \geq 0$. **(SUMMER 2022, 7 Marks)**
- **Q.** Solve the following Linear Programming problem using Simplex method. Maximize $Z = x_1 + 2x_2 + x_3$ subject to $2x_1 + x_2 - x_3 \leq 2$, $-2x_1 + x_2 - 5x_3 \geq -6$, $4x_1 + x_2 + x_3 \leq 6$, $x_1, x_2, x_3 \geq 0$. **(WINTER 2024, 7 Marks)**

Chapter 9: Constrained Optimization

Repeated Questions:

1. Lagrange Multiplier Method (Numerical):

- **Q.** Use Lagrange Multipliers to find the global maximum and minimum values of $f(x, y) = x^2 + 2y^2 - 4y$ subject to constraint $x^2 + y^2 = 9$. **(SUMMER 2025, 7 Marks; WINTER 2025, 7 Marks)**
- **Q.** A firm produces two goods, x and y. Due to a government quota, the firm must produce subject to the constraint $x + y = 42$. The firm's cost function is $c(x, y) = 8x^2 - xy + 12y^2$. Maximize the function using Lagrangian method. **(U3, 7 Marks OR; WINTER 2022, 7 Marks OR)**

2. Penalty Methods:

- **Q.** Explain the penalty methods for solving nonlinear programming with constraints. **(U3, 3 Marks OR; SUMMER 2022, 4 Marks; WINTER 2022, 3 Marks OR)**

Other Important Questions:

1. Lagrange Multiplier Method:

- **Q.** Explain Lagrange multiplier method. **(SUMMER 2022, 3 Marks)**
- **Q.** Minimize $f(x) = 4x_1^2 + 5x_2^2$ subject to $2x_1 + 3x_2 = 6$ using Lagrange multiplier method. **(SUMMER 2026, 4 Marks OR)**
- **Q.** Solve the following non-linear function with constraints using Lagrange multiplier method. [Data truncated in source – refer to the original question paper] **(WINTER 2024 OR)**

2. Kuhn-Tucker Conditions (Numerical):

- **Q.** Using the Kuhn-Tucker conditions minimize $f(X) = X_1^2 - X_2$ subject to $X_1 + X_2 = 6$, $X_1 - 1 \geq 0$, $X_1^2 + X_2^2 \leq 26$. **(WINTER 2022, 7 Marks)**

Chapter 10: Application of Optimizations

Repeated Questions:

1. General Applications and Profitability:

- **Q.** List the application(s) of optimization in chemical engineering / chemical process and plants. Explain any one in detail with example. **(U3, 7 Marks; WINTER 2024; SUMMER 2026, 3 Marks OR)**
- **Q.** Define the different measures of profitability/economic performance along with their significance. **(SUMMER 2025, 4 Marks OR; WINTER 2025, 4 Marks OR)**

2. Optimization of Process Equipment:

- **Q.** State objective functions in terms of the adjustable variable for chemical reactor. **(U3, 3 Marks; WINTER 2022, 3 Marks; SUMMER 2025, 3 Marks; SUMMER 2025, 3 Marks; WINTER 2025, 3 Marks; WINTER 2025, 3 Marks)**
- **Q.** Discuss the optimization of pipe diameter. **(U3, 4 Marks; WINTER 2022, 4 Marks)**
- **Q.** Explain the steps for finding the optimum L/D ratio for a pressurized cylindrical storage vessel. List all the variables and the important assumptions. / Determine the optimum L/D ratio for a cylindrical storage vessel. List the necessary assumptions. **(U3, 7 Marks OR; WINTER 2024 OR)**
- **Q.** Discuss the optimizing recovery of waste heat / water heat with suitable figure and equations. [Diagram required – refer to the original question paper] **(U3, 7 Marks; SUMMER 2022, 7 Marks; WINTER 2022, 7 Marks)**

3. Optimization in Data Fitting:

- **Q.** Explain the application of optimization in fitting vapor-liquid equilibrium data. **(U3, 4 Marks OR; WINTER 2022, 4 Marks OR)**

Other Important Questions:

1. Optimization of Separation and Heat Transfer Equipment:

- **Q.** Discuss the role of optimization in design and operation of binary distillation column with a focus on optimum reflux ratio. **(SUMMER 2026, 7 Marks)**
- **Q.** Describe the role of optimization in shell and tube heat exchanger design. **(WINTER 2024, 3 Marks)**

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