CAPE Laboratory

Spring Semester 2024 - 2025

Assignment - 2

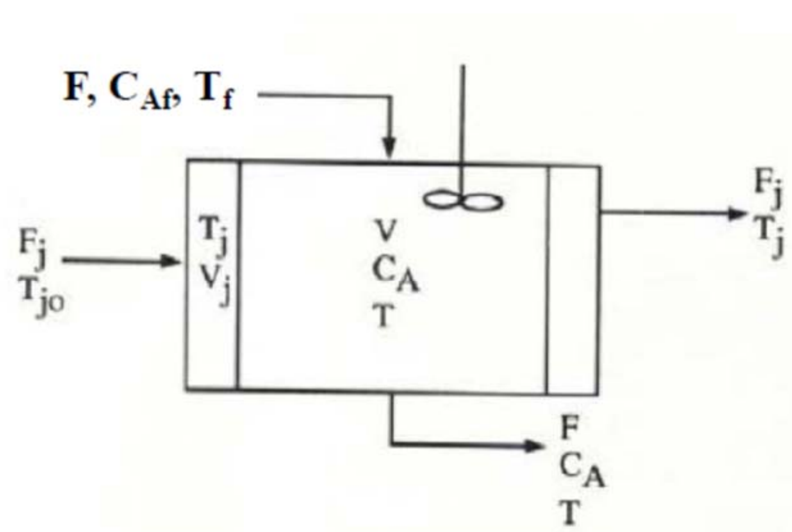
Objective: Numerical solution of a system of nonlinear algebraic equations.

This Assignment contains two problems. Solve both the problems.

Problem - 1:

Consider a perfectly mixed CSTR where a first-order exothermic irreversible reaction takes place (r = rate of reaction).

$$A \rightarrow B, \quad r = k_0 e^{\left(\frac{-E}{RT}\right)} C_A$$



Heat generated by reaction is being removed by the jacket fluid. The reactor volume (V) is constant.

Governing Equations:

(Subscript *j* indicates parameters related to jacket. Symbols carry their usual significance. Refer to the figure.)

Cont'd

$$V\frac{dC_A}{dt} = FC_{Af} - FC_A - rV$$

$$\rho C_p V\frac{dT}{dt} = \rho C_p F\left(T_f - T\right) + \left(-\Delta H\right)Vr - UA\left(T - T_j\right)$$

$$\rho_j C_j V_j\frac{dT_j}{dt} = \rho_j C_j F_j\left(T_{j0} - T_j\right) + UA\left(T - T_j\right)$$

Model Parameter Values:

Parameter	Value	Parameter	Value
F (m^3/h)	1	C_{Af} (kgmol/m^3)	10
V (m^3)	1	UA (kcal/°C h)	150
k_0 (h^{-1})	36×10^6	T_{j0} (K)	298
($-\Delta H$) (kcal/kgmol)	6500	($\rho_j C_j$) (kcal/m^3 °C)	600
E (kcal/kgmol)	12000	F_j (m^3/h)	1.25
(ρC_p) (kcal/m^3 °C)	500	V_j (m^3)	0.25
T_f (K)	298		

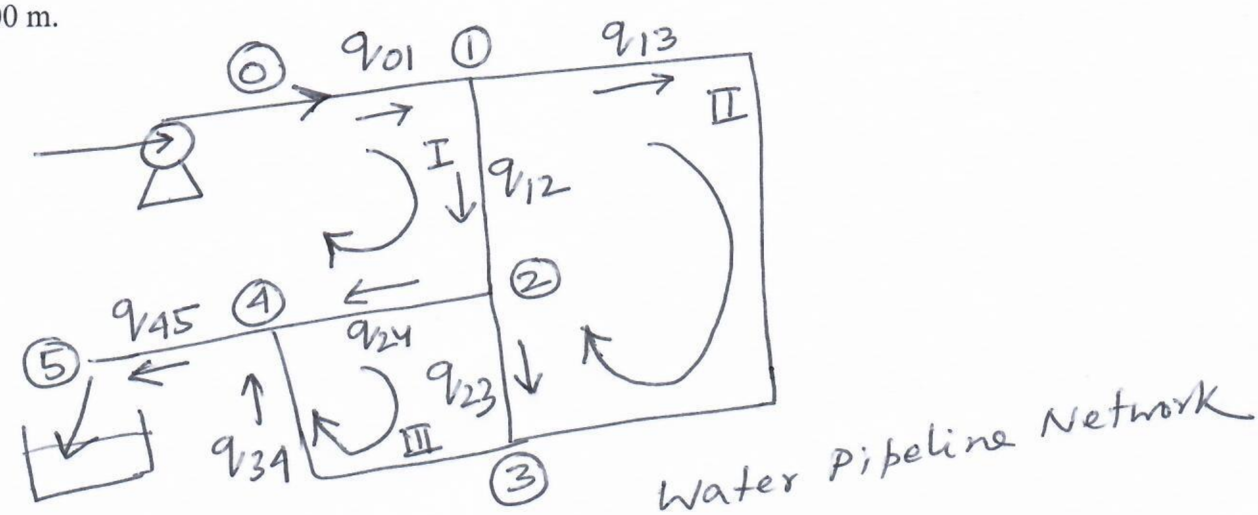
1. There are three steady states for this system. Identify all the steady states by setting LHS of the above ODE to zero and then solving the resulting algebraic equations simultaneously using Newton-Raphson method. Write your own code.

2. Solve the same problem using MATLAB function `fsolve` and compare your results.

Cont'd

Problem – 2:

Consider the following water pipeline network. All the pipes have insider diameter (D) of 0.154 m. The pressure at the exit of the pump is 15 bar above atmospheric. The water is discharged at atmospheric pressure at the end of the pipeline. The equivalent lengths of the pipes connecting different nodes are: L_{01} = 100 m, $L_{12} = L_{23} = L_{45}$ = 300 m, and $L_{13} = L_{24} = L_{34}$ = 1200 m.



1. Calculate all the flow rates and pressures at nodes 1, 2, 3, and 4.

2. Suppose the pipeline between node 2 to node 4 becomes blocked. Calculate how the flow rates and pressure drops will change.

Given:

The pressure drop from node i to node j can be expressed as $\Delta P_{ij} = k_{ij}(q_{ij})^2$ where q_{ij} is the volumetric flow rate between nodes i and j. The terms k_{ij} are given as

$$k_{ij} = \frac{2 f_F \rho \Delta L_{ij}}{\pi^2 D^5}$$

Assume Fanning friction factor, f_F = 0.005 for all pipelines.

Take the density of water as, $\rho = 1000\ \text{kg/m}^3$.