GUJARAT TECHNOLOGICAL UNIVERSITY

BE 3 SEMESTER – OLD PAPER – SUMMER 2022 TO SUMMER 2026 – QUESTION BANK

Subject Name & Code: Control System Theory - 3130905

Chapter 1: Introduction to Control Problem

Repeated Questions:

1. Basics of Control Systems (Theory):

- **Q.** Define control system and give classification of control systems / Define the following terms: 1. Control system 2. Plants 3. Process. **(SUMMER 2022, 3 Marks; SUMMER 2023, 3 Marks; WINTER 2024, 3 Marks)**
- **Q.** Compare open loop and closed loop control systems / What are the limitations of open-loop systems over closed-loop systems? List the advantages of closed-loop system over open-loop system. **(WINTER 2022, 4 Marks; WINTER 2023, 4 Marks; SUMMER 2025, 4 Marks; SUMMER 2026, 4 Marks)**

2. Transfer Function (Theory):

- **Q.** Define transfer function and state advantages and disadvantages of transfer function / Define the transfer function of a system. **(SUMMER 2022, 4 Marks; SUMMER 2023, 4 Marks; SUMMER 2025, 4 Marks; WINTER 2025, 4 Marks; SUMMER 2026, 4 Marks)**

3. Block Diagram Reduction and Signal Flow Graph:

- **Q.** Determine the transfer function of the system shown in figure by using block diagram reduction technique. [Diagram required – refer to the original question paper] **(SUMMER 2022, 7 Marks; WINTER 2022, 7 Marks; SUMMER 2023, 7 Marks; WINTER 2023, 7 Marks OR; WINTER 2024, 7 Marks; WINTER 2025, 7 Marks)**
- **Q.** Define the following terms related to signal flow graph: Source node, Sink node, Chain node. **(SUMMER 2022, 4 Marks - Dummy node also asked; WINTER 2023, 3 Marks)**

4. Mechanical Systems and Analogies (Numerical):

- **Q.** Determine the transfer function for the given mechanical system and draw equivalent electrical circuit for F-V analogy. [Diagram required – refer to the original question paper] **(SUMMER 2022, 7 Marks; WINTER 2024, 7 Marks; SUMMER 2025, 7 Marks)**

Other Important Questions:

1. Control Systems – Basics (Theory):

- **Q.** Explain closed loop control system with suitable example in detail. **(SUMMER 2022, 7 Marks)**
- **Q.** Explain open loop control system with suitable example in detail. **(SUMMER 2026, 7 Marks)**
- **Q.** Draw the block diagrams of open loop and closed loop control systems. **(WINTER 2023, 3 Marks)**
- **Q.** Compare conventional control method and modern control method. **(WINTER 2023, 4 Marks)**
- **Q.** What are the components of feedback control system? **(WINTER 2024, 4 Marks)**

2. Transfer Function and Laplace Transform (Theory):

- **Q.** Define transfer function and state methods to find transfer function of control system. **(SUMMER 2022, 3 Marks)**
- **Q.** Define the following terms: 1. Transfer function 2. Summing point 3. Take off point. **(SUMMER 2025, 3 Marks)**
- **Q.** Explain properties of Laplace transform. **(WINTER 2025, 3 Marks)**

3. Block Diagram Reduction Rules (Theory):

- **Q.** Explain block reduction technique for (a) shifting a summing point after the block (b) shifting a take-off point before a block (c) shifting a take-off point after a summing point. **(SUMMER 2024)**
- **Q.** Explain block diagram reduction technique rules to find overall transfer function of control system. **(SUMMER 2025, 7 Marks)**
- **Q.** Describe the rules to reduce the Block Diagram to find transfer function of the control system. **(SUMMER 2026, 7 Marks OR)**

4. Mechanical Systems and Analogies:

- **Q.** Prepare table showing analogous quantities of Electrical and mechanical translation systems for F-V and F-I analogy. **(SUMMER 2022, 4 Marks)**
- **Q.** Determine the overall transfer function for the mechanical translational system shown in fig.1. [Diagram required – refer to the original question paper] **(WINTER 2023, 7 Marks)**
- **Q.** Obtain the transfer function $X_1(s)/F(s)$ and $X_2(s)/F(s)$ of the mechanical system shown in figure. [Diagram required – refer to the original question paper] **(WINTER 2022)**
- **Q.** Determine the transfer function for the given mechanical system shown in figure and also draw the equivalent mechanical circuit. [Diagram required – refer to the original question paper] **(SUMMER 2026, 7 Marks)**

5. Electrical Circuits and D.C. Motors (Numerical / Derivation):

- **Q.** Obtain the transfer function of the circuit shown in the figure. Comment on the response of the system for $R_1 = R_2 = 1$ MΩ, $C_1 = 1$ µF, $C_2 = 0.5$ µF. [Diagram required – refer to the original question paper] **(SUMMER 2024)**
- **Q.** Draw schematic diagram of Field controlled D.C. Motor and derive its transfer function. **(SUMMER 2022, 7 Marks OR)**
- **Q.** Derive the transfer function of an armature-controlled D.C. motor. **(SUMMER 2025, 7 Marks OR)**

Chapter 2: Time Response Analysis

Repeated Questions:

1. Test Signals and First-Order System (Theory):

- **Q.** Explain Standard Test Signals used in control system / Define the standard test signals. **(WINTER 2022, 3 Marks; WINTER 2023, 4 Marks; WINTER 2024, 3 Marks; SUMMER 2025, 3 Marks; SUMMER 2026, 3 Marks)**
- **Q.** Explain the time constant of the first-order system. **(SUMMER 2023, 4 Marks; WINTER 2024, 4 Marks)**

2. Time Response Specifications (Theory):

- **Q.** Define / explain time response specifications such as delay time, rise time, peak time, settling time and peak overshoot (neat sketch / time response graph asked in some papers). [Diagram required – refer to the original question paper] **(SUMMER 2022, 3 Marks; SUMMER 2022, 7 Marks; WINTER 2022, 3 Marks; WINTER 2023, 7 Marks; SUMMER 2025, 3 Marks; SUMMER 2026, 4 Marks)**

3. Stability – Routh-Hurwitz Criterion (Numerical):

- **Q.** Determine stability using Routh-Hurwitz criterion for the given characteristic equation. [Characteristic equation differs in each paper – refer to the original question papers] **(SUMMER 2022, 4 Marks; WINTER 2022 OR; SUMMER 2024; SUMMER 2025; WINTER 2025, 7 Marks OR; SUMMER 2026)**

4. Root Locus (Numerical):

- **Q.** Draw / Sketch the root locus for the transfer function $G(s) = K/[s(s+4)(s^2+4s+20)]$. **(WINTER 2023, 7 Marks; SUMMER 2026, 7 Marks)**

Other Important Questions:

1. Time Response – Definitions and First-Order System (Theory):

- **Q.** Define (a) Time response (b) Transient response (c) Steady state response. **(SUMMER 2024)**
- **Q.** Explain with example the first order system. **(WINTER 2025, 3 Marks)**
- **Q.** Solve expression of response of first order system for unit step and unit impulse. Is it possible to get impulse response if step response is available? **(WINTER 2025, 7 Marks)**
- **Q.** Distinguish between type and order of the system. **(WINTER 2024, 3 Marks)**
- **Q.** Draw the step response for damping ratio (i) $\zeta = 1$ (ii) $\zeta < 1$ (iii) $\zeta > 1$. [Diagram required – refer to the original question paper] **(SUMMER 2026)**

2. Second-Order System – Time Response (Numerical):

- **Q.** Obtain the final value of c(t) if the input r(t) is of 1.5 units for $C(s)/R(s) = 100/(s^2+7s+25)$. **(SUMMER 2024)**
- **Q.** For $\theta_s(s)/T(s) = 1/(Js^2+fs+K)$, a step input of 10 N-m is applied. Design J, f and K for $M_p = 6\%$, $t_p = 1$ sec and steady state output 0.5 radian. **(SUMMER 2024)**
- **Q.** Maximum overshoot for unity feedback system $G(s) = K/[s(sT+1)]$ is to be reduced from 60% to 20%. Design K. **(SUMMER 2024 OR)**
- **Q.** For system $G(s) = 15/[(s+1)(s+3)]$, $H(s) = 1$, determine characteristic equation, damping ratio and undamped frequency. **(SUMMER 2022, 4 Marks)**
- **Q.** For second order unity feedback system $G(s) = 200/[s(s+8)]$, obtain response specification. **(SUMMER 2023)**
- **Q.** Unity feedback system $G(s) = K/[s(Ts+1)]$. By what factor should the amplifier gain be reduced so that the peak overshoot reduces from 75% to 25%? **(WINTER 2025, 7 Marks)**
- **Q.** Calculate damping ratio and undamped natural frequency for unity feedback servo system $G(s) = 10/[(s+2)(s+5)]$. **(SUMMER 2026)**

3. Stability – Routh Criterion and Roots Criterion:

- **Q.** Determine stability using roots criterion $s^3+6s^2+11s+6 = 0$. **(SUMMER 2023)**
- **Q.** Characteristic equation $s^4+20s^3+s^2+2s+K = 0$: find the range of K for stability; can the system be marginally stable? Find K and frequency. **(WINTER 2023, 7 Marks)**
- **Q.** For $s^4+22s^3+10s^2+s+K$, find K_{marg} and ω_{marg}. **(WINTER 2024, 4 Marks)**
- **Q.** Explain Routh stability criterion method. **(WINTER 2023, 4 Marks)**
- **Q.** Decide how stability can be ensured from Routh Table. **(WINTER 2025, 4 Marks)**
- **Q.** State advantages and limitations of Routh's criteria. **(SUMMER 2026, 3 Marks)**

4. Root Locus – Theory:

- **Q.** Explain constructional rules for Root Locus Technique. **(SUMMER 2022, 7 Marks)**
- **Q.** List all the rules to construct a root locus and explain. **(SUMMER 2023, 7 Marks)**
- **Q.** Explain terms with respect to root locus: centroid; angle of arrival and angle of departure; breakaway and break-in points. **(WINTER 2022)**

5. Root Locus – Numerical:

- **Q.** Draw the root locus for unity feedback $G(s)H(s) = K(s+1)(s+2)/[(s+0.1)(s-1)]$. Find K for critically damped. **(WINTER 2022, 7 Marks)**
- **Q.** Sketch root locus for unity feedback $G(s) = K/[s(s+1)(s+3)]$ and determine K for marginal stability. **(SUMMER 2023, 7 Marks)**
- **Q.** Draw the root locus for $G(s)H(s) = K/[s(s^2+2s+2)]$. Comment on stability and response. **(SUMMER 2024)**
- **Q.** Draw the root locus for $G(s)H(s) = K/[s(s+1)(s+2)(s+3)]$. Comment on stability and response. **(SUMMER 2024, 7 Marks)**
- **Q.** Draw root locus for $G(s) = K/[s(s^2+4s+20)]$. **(WINTER 2024, 7 Marks)**

Chapter 3: Frequency-Response Analysis

Repeated Questions:

1. Nyquist Stability Criterion (Theory):

- **Q.** State and explain Nyquist stability criteria / Write Nyquist contour and Nyquist stability criterion in brief / Explain Nyquist stability criterion. **(SUMMER 2022, 7 Marks; WINTER 2022, 4 Marks; SUMMER 2023, 3 Marks; WINTER 2023, 7 Marks; WINTER 2024, 7 Marks; SUMMER 2026, 7 Marks)**
- **Q.** State the condition for stability of control system with respect to Bode plot and Nyquist stability criterion. **(WINTER 2023, 3 Marks; SUMMER 2026, 3 Marks)**

2. Gain Margin, Phase Margin and Frequency-Domain Terms (Theory):

- **Q.** Explain / Define Gain margin and Phase margin / Define (a) gain margin (b) phase margin (c) cut-off frequency / Define: Gain Margin, Phase Margin, Bandwidth, Resonant Frequency, Gain Crossover Frequency, Frequency Domain, Resonant Peak. **(SUMMER 2022, 3 Marks; SUMMER 2023, 4 Marks; WINTER 2023, 3 Marks; SUMMER 2024; WINTER 2024, 3 Marks; WINTER 2025, 7 Marks)**

3. Frequency Response / Bode Plot – Advantages and Limitations (Theory):

- **Q.** State advantages and limitations of frequency response analysis / Bode plot. **(SUMMER 2022, 4 Marks; WINTER 2022, 3 Marks; SUMMER 2023, 3 Marks; WINTER 2023, 3 Marks; WINTER 2025, 3 Marks; SUMMER 2026, 4 Marks)**

4. Polar Plot:

- **Q.** Sketch / Draw polar plot for the given transfer function. [Diagram required – refer to the original question paper] **(SUMMER 2023, 4 Marks - G(s) = 10/(s+1); WINTER 2023, 4 Marks - G(s) = 2/[(s+1)(s+2)(s+3)]; WINTER 2024, 4 Marks - G(s) = 1+sT; SUMMER 2025, 4 Marks - G(s) = 5/[(s+1)(s+2)]; SUMMER 2026, 4 Marks - G(s) = 10/[s(s+2)])**
- **Q.** Write a brief note / describe polar plots with sketch of simple example. [Diagram required – refer to the original question paper] **(WINTER 2022; SUMMER 2023, 3 Marks; WINTER 2025, 3 Marks)**

5. Bode Plot (Numerical):

- **Q.** Draw Bode plot for the given transfer function and determine gain margin, phase margin, crossover frequencies and stability. [Diagram required – refer to the original question paper] **(WINTER 2022 - G(s) = 10/[s(1+0.5s)(1+0.01s)]; SUMMER 2023 - G(s) = 10/[s(s+1)(s+5)]; SUMMER 2024 - G(s) = 80/[s(s+2)(s+20)]; SUMMER 2025 - G(s)H(s) = 4/[s(1+0.5s)(1+0.08s)])**

Other Important Questions:

1. Frequency-Domain Terms and Relations (Theory):

- **Q.** Define (a) resonant peak (b) resonant frequency (c) cut-off rate. **(SUMMER 2024, 3 Marks)**
- **Q.** Explain relationship between time and frequency response. **(WINTER 2022)**
- **Q.** State the Nyquist stability criteria. Why are Nyquist criteria called frequency response method? **(WINTER 2025, 3 Marks)**
- **Q.** State the advantages of Nyquist plot. **(SUMMER 2025, 3 Marks)**
- **Q.** Define gain margin and phase margin when gain and phase crossover frequency is zero and infinity in Bode plot. [Diagram required – refer to the original question paper] **(WINTER 2025, 4 Marks)**
- **Q.** Explain how to determine gain crossover frequency and phase crossover frequency from Bode plot. [Diagram required – refer to the original question paper] **(WINTER 2025, 4 Marks)**
- **Q.** Write applications of frequency response methods. **(WINTER 2025, 4 Marks)**

2. Nyquist Plot and Corner Frequencies (Numerical):

- **Q.** Calculate corner frequencies for G(s) = 50(1+0.1s)/[s(s+20)(0.02s+1)]. **(SUMMER 2022, 3 Marks)**
- **Q.** Draw Nyquist plot for closed loop transfer function G(s)H(s) = 10/[(s+1)(s+2)]. [Diagram required – refer to the original question paper] **(SUMMER 2023)**
- **Q.** Draw Nyquist plot for G(s)H(s) = 10/[s(s+1)]. [Diagram required – refer to the original question paper] **(SUMMER 2023, 7 Marks)**
- **Q.** Unity feedback G(s) = 10/[s(s+1)(s+2)]. Draw Nyquist plot and comment on closed-loop stability. [Diagram required – refer to the original question paper] **(SUMMER 2024 OR)**

Chapter 4: Introduction to Controller Design

Repeated Questions:

1. Compensation (Theory):

- **Q.** Define compensation and list out different types of compensations. **(WINTER 2022, 4 Marks; SUMMER 2023, 3 Marks; WINTER 2023, 3 Marks; WINTER 2024, 3 Marks; SUMMER 2025, 3 Marks; WINTER 2025, 3 Marks; SUMMER 2026, 3 Marks)**

2. Controllers (Theory):

- **Q.** List out different types of Controllers. **(SUMMER 2022, 3 Marks; WINTER 2023, 3 Marks)**
- **Q.** Explain derivative control mode and state its characteristics / effect / Explain effect of PD controller on second order system / Explain significance of integral and derivative controller in PID. **(SUMMER 2022, 3 Marks; SUMMER 2023, 7 Marks; WINTER 2023, 4 Marks; WINTER 2024, 3 Marks; SUMMER 2025, 4 Marks; SUMMER 2026, 4 Marks)**
- **Q.** Explain PID controller / Write a note on PID controller. **(SUMMER 2023, 3 Marks; WINTER 2023, 7 Marks; SUMMER 2025, 7 Marks; SUMMER 2026, 7 Marks)**
- **Q.** Explain PI controller / characteristics / effect. **(SUMMER 2022, 4 Marks; SUMMER 2024, 4 Marks; WINTER 2024, 4 Marks; WINTER 2025, 3 Marks)**

3. Lag Compensator (Theory):

- **Q.** Explain design / procedure of Lag compensator. **(SUMMER 2022, 7 Marks; WINTER 2022, 7 Marks; WINTER 2023, 7 Marks; WINTER 2025, 7 Marks; SUMMER 2026, 7 Marks)**
- **Q.** State limitations and effects of Lag compensator. **(WINTER 2022, 3 Marks; SUMMER 2026, 3 Marks)**

4. Steady-State Error and Error Constants:

- **Q.** Steady-state error and error constants (variant asked in each paper is given in the bracket). **(SUMMER 2023, 3 Marks - explain steady state error; SUMMER 2023, 7 Marks - find Kp, Kv, Ka and steady state error; SUMMER 2024 - ramp input steady state error; WINTER 2024, 7 Marks OR - Type 0/1/2 and steady state error; WINTER 2025, 4 Marks - note on steady state error and error constants; SUMMER 2026, 4 Marks - derive steady state error constants for Type-1 system for step input)**

Other Important Questions:

1. Compensation – Basics (Theory):

- **Q.** Define compensation. Explain series compensation. **(SUMMER 2024, 3 Marks)**
- **Q.** Define compensation and explain series-parallel compensation. **(WINTER 2023, 3 Marks)**
- **Q.** State various compensation networks and different methods of compensation. **(SUMMER 2025, 3 Marks)**

2. Controllers (Theory):

- **Q.** Explain effect of integral control action on system performance. **(WINTER 2022, 3 Marks)**
- **Q.** Explain Integral control mode and state its characteristics. **(SUMMER 2023, 4 Marks)**

3. Lead Compensator:

- **Q.** State limitations of a single stage phase lead compensation. **(WINTER 2022, 4 Marks)**
- **Q.** Draw Bode plot for phase-lead network and derive expression for α in terms of Φ_m. [Diagram required – refer to the original question paper] **(WINTER 2022, 7 Marks)**
- **Q.** Explain design in frequency domain of lead compensation. **(SUMMER 2023, 4 Marks)**
- **Q.** State limitations and effects of phase Lead compensation. **(WINTER 2023, 4 Marks)**
- **Q.** Explain design of lead compensator using Bode plot. [Diagram required – refer to the original question paper] **(WINTER 2024, 7 Marks OR)**

- **Q.** Draw the circuit of lead compensator and lag compensator. [Diagram required – refer to the original question paper] **(SUMMER 2025, 3 Marks)**

4. Lag Compensator and Lag-Lead Compensator:

- **Q.** Draw passive lag compensating network. Write standard transfer function and draw PZ map and Bode plot. [Diagram required – refer to the original question paper] **(SUMMER 2024)**
- **Q.** List advantages and disadvantages of phase lag network. **(WINTER 2024, 4 Marks)**
- **Q.** Draw and explain polar plot of lag-lead network. [Diagram required – refer to the original question paper] **(SUMMER 2025, 4 Marks)**
- **Q.** Explain the design of Lag-Lead compensator using Root Locus. **(SUMMER 2025, 7 Marks)**
- **Q.** Explain Bode plot of Lag-Lead compensator. [Diagram required – refer to the original question paper] **(WINTER 2025, 4 Marks)**

5. Root Locus Design:

- **Q.** Explain step by step procedure to obtain Root locus design. **(WINTER 2025, 7 Marks OR)**

Chapter 5: State Variable Analysis

Repeated Questions:

1. State Variable Basics (Theory):

- **Q.** Define state variable, state vector and state space / Define state variable, state trajectory, state vector / Define state, state variables, state space, state transition matrix. **(SUMMER 2022, 3 Marks; WINTER 2022, 4 Marks; SUMMER 2024, 3 Marks; WINTER 2024, 3 Marks; SUMMER 2025, 3 Marks; WINTER 2025, 3 Marks; SUMMER 2026, 3 Marks)**
- **Q.** State advantages of state variable analysis / state space approach / state space representation. **(SUMMER 2022, 4 Marks; SUMMER 2024, 3 Marks; WINTER 2024, 3 Marks OR)**
- **Q.** State / Explain properties of state transition matrix. **(SUMMER 2024, 4 Marks; WINTER 2024, 4 Marks; SUMMER 2025, 3 Marks; SUMMER 2026, 4 Marks)**

2. Controllability and Observability:

- **Q.** Explain controllability and observability / Check controllability and observability for given state model. [Diagram required – refer to the original question paper] **(WINTER 2022, 4 Marks; WINTER 2023; SUMMER 2024; WINTER 2024, 4 Marks OR; WINTER 2024, 7 Marks; SUMMER 2025, 4 Marks; WINTER 2025, 7 Marks; SUMMER 2026, 7 Marks)**

3. State Model of Electrical Circuit (Numerical):

- **Q.** Draw series RLC circuit and obtain state space model considering current and capacitor voltage as state variables. **(WINTER 2022, 7 Marks; WINTER 2024, 7 Marks OR)**

Other Important Questions:

1. State Model – Derivations and Transfer Function:

- **Q.** Obtain the state variable equation $\dot{x} = Ax + Bu$, $y = Cx + Du$ and draw the state diagram. **(SUMMER 2023, 3 Marks OR)**
- **Q.** Obtain the state variable equation. **(SUMMER 2023, 7 Marks)**
- **Q.** Derive the transfer function for a system with state model $\dot{x} = Ax + bu$, $y = Cx + Du$. **(SUMMER 2024)**
- **Q.** Assuming zero initial conditions, derive the transfer function for the system described by the standard state variable model. **(WINTER 2025, 7 Marks)**
- **Q.** Consider state model with given A, B, C matrices and obtain its transfer function. [Diagram required – refer to the original question paper] **(SUMMER 2024)**
- **Q.** Obtain state space representation for transfer function $C(s)/R(s) = 1/(s^2+2s+3)$. Comment on controllability and observability. **(WINTER 2023)**

2. State Variable Approach – Theory:

- **Q.** State advantages and limitations of state model using phase variables. **(SUMMER 2025, 4 Marks)**
- **Q.** Distinguish state variable approach versus classical transfer function approach. **(WINTER 2025, 4 Marks)**

3. State Model of Physical Systems (Numerical):

- **Q.** Obtain state space representation of the given electrical circuit. [Diagram required – refer to the original question paper] **(SUMMER 2025, 7 Marks)**
- **Q.** Obtain the state model of the given mechanical model. [Diagram required – refer to the original question paper] **(SUMMER 2025, 7 Marks)**

4. Unidentified Question:

- **Q.** [Data truncated in source – refer to the original question paper] **(WINTER 2023, 3 Marks)**

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