Enrollment No./Seat No.:

# GUJARAT TECHNOLOGICAL UNIVERSITY

**Bachelor of Engineering - SEMESTER - VI EXAMINATION - WINTER 2025**

**Subject Code: 116AO01** **Date: 06-12-2025**

**Subject Name: Control of Robotic Systems**

**Time: 02:30 PM TO 05:00 PM** **Total Marks: 70**

**Instructions**

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Simple and non-programmable scientific calculators are allowed.**

| | | | Marks |
|---|---|---|---|
| **Q.1** | **(a)** | Define transfer function and give its significance in control systems. | **03** |
| | **(b)** | What is the difference between open-loop and closed-loop control? | **04** |
| | **(c)** | Draw and explain a Nyquist plot and describe how it helps in determining system stability. | **07** |
| **Q.2** | **(a)** | What are P, PI, and PID controllers? | **03** |
| | **(b)** | Differentiate between transfer function and state-space model. | **04** |
| | **(c)** | Explain Bode plot analysis for determining gain margin and phase margin of a system. | **07** |
| | | **OR** | |
| | **(c)** | Design a PID controller for a simple robotic manipulator and explain its working. | **07** |
| **Q.3** | **(a)** | Explain the concept of observer design in control systems. | **03** |
| | **(b)** | Explain the describing function method for analyzing non-linear systems. | **04** |
| | **(c)** | Explain Liapunov's method for determining stability of non-linear systems in detail. | **07** |
| | | **OR** | |
| | **(a)** | What is the significance of phase-plane method in control systems? | **03** |
| | **(b)** | Explain the characteristics of a common physical non-linear system. | **04** |
| | **(c)** | A unity feedback system has open-loop transfer $L(s) = K / [s (s + 4)]$. (a) Determine range of K for closed-loop stability. (b) Find gain margin and phase margin at $K = 8$. | **07** |
| **Q.4** | **(a)** | For characteristic equation $s^3 + 6 s^2 + 11 s + K = 0$, use Routh-Hurwitz to find range of K for stability. | **03** |
| | **(b)** | Explain Cartesian control and joint-based control in robotics. | **04** |
| | **(c)** | Explain trajectory generation techniques used for robotic manipulators with suitable examples. | **07** |
| | | **OR** | |
| | **(a)** | Define hybrid position/force control. | **03** |

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|---|---|---|---|
| | **(b)** | Explain force control in robotic manipulators. | **04** |
| | **(c)** | A robot must apply a constant normal force of 30 N while tracking position normal to surface with stiffness 1000 N/m. If position control has PI controller with P=500 N/m, I=1000 N/(m·s), derive closed-loop stiffness seen by environment and compute steady-state position error under 30 N load. | **07** |
| **Q.5** | **(a)** | Define non-linear system with suitable examples. | **03** |
| | **(b)** | Explain the procedure for constructing a root locus diagram. | **04** |
| | **(c)** | For point-to-point move of 300 mm with trapezoid profile and max accel 2000 mm/s², minimum time (bang-bang) = 2 √(distance / a). Compute minimal time. | **07** |

**OR**

| | | | |
|---|---|---|---|
| | **(a)** | List different frequency response plots used in control system analysis. | **03** |
| | **(b)** | Define controllability and observability. | **04** |
| | **(c)** | Discuss the process of system analysis using describing function and phase-plane methods. | **07** |

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