Duration: 3 Hours **Max. Marks 80**

N.B.

1. **Q.1** is compulsory. Attempt **any three** from the remaining questions.
2. All questions carry equal marks.
3. Figures to the Right indicate full marks.
3. Assume suitable data if necessary

Q.1 Attempt **any four** **20**

a. Write the practical limitations of the perfect control.

b. Define the sliding surface that will converge the trajectory of the system to the equilibrium if it is restricted on it.

c. Write the limitation of sliding mode control. How to overcome this limitation?

d. Obtain the classical controller $c(s)$ for the plant transfer function $\tilde{p}(s)$ via block diagram reduction from IMC structure with controller $q(s)$.

e. Solve the following-

(i) $[1.15, 2.15] - [0.7, 1.7]$

(ii) $[1, 2] \div [0.5, 1]$

f. Write the properties of Hurwitz polynomial.

Q.2 A. What is Hermite-Biehler theorem for Hurwitz polynomial? Give the proof. **10**

B. Write the Kharitonov's theorem for the stability of real interval polynomial. **10**

Q.3 A. Design the sliding mode control for the following system so that sliding motion is characterised by eigen values $-0.707 \pm 0.707j$ **10**

$$
\begin{aligned}
\dot{x}_1 &= x_2 \\
\dot{x}_2 &= x_3 \\
\dot{x}_3 &= x_1 + x_2 + x_3 + u + 0.5\sin 10t
\end{aligned}
$$

B. Prove that- $\dot{z} = -k\,\mathrm{sgn}(z)$, $k > 0$ is finite time stable. **10**

Q.4 A. Write the various reaching laws used in sliding mode design. Explain the disadvantage of power rate reaching law. **10**

B. Transform the following system into regular form **10**

$$
\dot{x} = \begin{pmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 2 \end{pmatrix} x + \begin{pmatrix} -1/4 \\ -1 \\ -3/4 \end{pmatrix} u \quad \text{and} \quad y = \begin{pmatrix} -2/3 & -1/3 & 2/3 \end{pmatrix} x
$$

Turn Over

Q.5 A. Check if the following system is robustly stable, **10**

$$G(s) = \frac{\delta_1 s + \delta_0}{s^2(\delta_4 s + \delta_3)}$$

where, $\delta_0 \in [22, 26], \delta_1 \in [48, 52], \delta_2 \in [34, 36], \delta_3 \in [9, 11]$ and $\delta_4 \in [0.5, 1.5]$

B. Outline the design procedure of quantitative feedback control. **10**

Q.6 A. Design the IMC based PID control for the system, **10**

$$\tilde{G}(s) = \frac{e^{-4s}}{3s + 1}$$

B. Design the IMC control for the system with model **10**

$$\tilde{G}(s) = \frac{(-0.5s + 1)e^{-2s}}{s^2 + 3s + 2}$$

Compute the unit step response of the system in absence of disturbance if model is perfect.

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