B.E. Instrumentation Engineering Sixth Semester

# IN603 - Control System Design

P. Pages : 3 **GUG/W/18/1709**

Time : Three Hours * 1 3 4 3 * Max. Marks : 80

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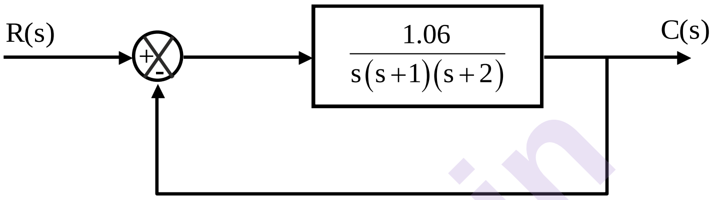
Notes :
1. Same answer book must be used for each question.
2. All questions carry marks as indicated.
3. Assume suitable data wherever necessary.
4. Illustrate your answers wherever necessary with the help of neat sketches.

**1.** Consider the system shown below. **16**




Build a lag compensator to satisfy following specifications.

i) Damping ratio, Z = 0.5.

ii) Undamped natural frequency, $\omega_n = 0.67\ \text{rad}/\text{sec}$.

ii) Velocity error constant, $k_v = 5\ \text{sec}^{-1}$.

**OR**

**2.** Design a cascade lead compensator for the system with open loop transfer function **16**

$$G(s) = \frac{k}{s(s+2)(s+8)}.$$

to meet following specifications-

i) Undamped natural frequency, $\omega_n = 4\ \text{rad}/\text{sec}$.

ii) Damping ration, Z = 0.5.

**3.** The open loop transfer function of a control system is **16**

$$G(s)H(s) = \frac{10}{s(1+0.5s)(1+0.1s)}.$$

a) Draw the bode plot and determine gain and phase margin.

b) A lead compensator with transfer function

$D(s) = \dfrac{(1+0.23s)}{(1+0.023s)}$ is now inserted in the forward path. Determine the new phase and gain margins. Comment upon the effects of lead compensation on system performance.

**OR**

**4.** Consider an open loop transfer function **16**

$$G(j\omega) = \frac{5}{j\omega(j\omega+1)(0.25j\omega+1)}.$$

Construct a lag compensator, so that the velocity error constant $k_v \geq 5$ and the phase margin of the system be at least 45°.

**5.** a) The plant is given by $\dot{x} = Ax + bu$ **10**

where, $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -6 \end{bmatrix}, b = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

The system uses state feedback control $u = -kx$. Consider the desired closed loop poles at $s = -2 + j4, s = -2 - j4, s = -10$. Determine the state feedback gain matrix 'k' by direct substitution method?

b) Investigate controllability and observability. **6**

$$\dot{x} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -2 & 1 \\ 0 & 0 & -1 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \\ -2 \end{bmatrix} u.$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} x.$$

**OR**

**6.** a) Consider a system given as $G(s) = \frac{s+3}{s^2+3s+2}$ **8**

obtain state space representation in first companion, second companion and Jordan canonical form?

b) Consider the system **8**

$$\dot{x} = \begin{bmatrix} 0 & 0 & -2 \\ 0 & 1 & 0 \\ 1 & 0 & 3 \end{bmatrix} x; \ x(0) = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}.$$

Evaluate state transition matrix and deduce the time response of a system.

**7.** A unity feedback system has an open loop transfer function **16**

$$G(s) = \frac{1}{s(s+2z)}$$

For unit step input, compute the following :

a) $ISE = \int_0^\infty e^2(t)\,dt.$

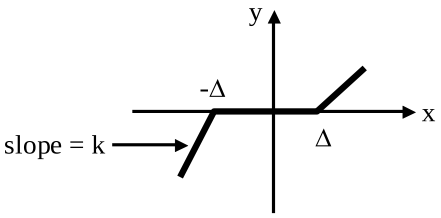
b) $ITSE = \int_0^\infty te^2(t)\,dt.$

**OR**

**8.** a) Enlist the different performance indices? Give the significance of each performance index with suitable example. **8**

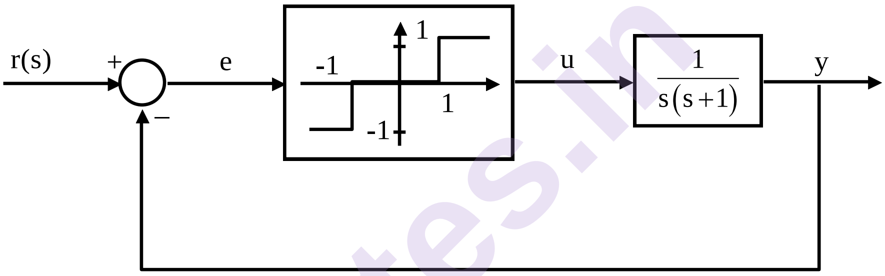
b) For a unity feedback second order system compute the value of damping ratio which minimizes ISE for a unit step input? Also calculate the minimum value of ISE? $(\omega_n = 1)$. **8**

**9.** Evaluate the Describing function of the following Nonlinearity. **16**




**OR**

**10.** a) Consider the following system given in a figure. **12**




Plot the phase trajectories using method of isoclines.

b) Write a short note on limit cycles. **4**

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