Code : 100502

B.Tech 5th Semester Exam., 2021

(New Course)

CONTROL SYSTEMS

Time : 3 hours *Full Marks* : 70

Instructions :

(i) The marks are indicated in the right-hand margin.

*(ii) There are **NINE** questions in this paper.*

*(iii) Attempt **FIVE** questions in all.*

*(iv) Question No. **1** is compulsory.*

1. Attempt any *seven* : 2×7=14

(a) Define a closed-loop control system using an example.

(b) Find transfer function of a series *R-L* circuit.

(c) Define gain margin and phase margin using Bode plot.

(d) Define gain cross-over frequency and phase cross-over frequency using Bode plot.

(e) Explain BIBO stability and develop the expression for it.

(f) Define minimum phase, non-minimum phase and all-pass transfer functions.

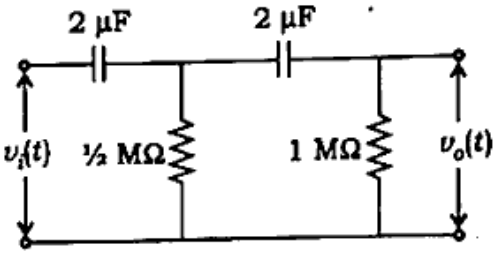
(g) Discuss the effects of *(i)* addition of zeros and *(ii)* addition of poles on root locus.

(h) Define gain margin and phase margin using polar plot.

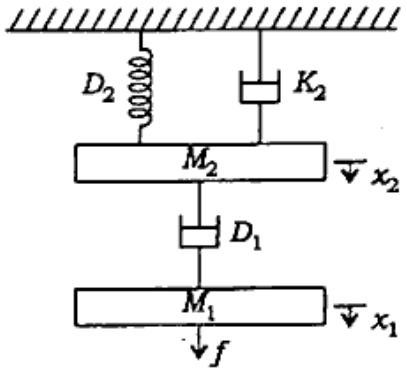
(i) State Nyquist criterion. Write the advantages of Nyquist plot.

(j) What do you mean by describing function?

2. *(a)* Derive the transfer function of the network shown below :



(b) Find the equations of the system shown in figure below :



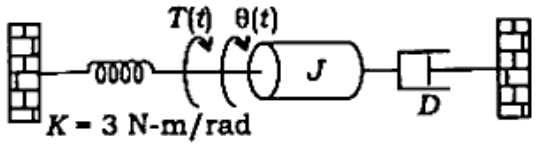
(c) Write and explain block diagram reduction rules. 5+5+4=14

3. (a) Consider a unity feedback control system with forward path gain A, feedback path gain H and forward path transfer function

$$G(s) = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

with $\omega_n = 8\pi / T$, $T = 6 \cdot 28$ sec and $\xi = 0 \cdot 3$. Calculate the open-loop and closed-loop sensitivities for changes in A and H.

(b) Derive peak overshoot. Find J and D for the system shown in figure below to yield 35% peak overshoot and a settling time of 1·5 seconds (for 2% error band) for a step input of torque $T(t)$:



7+7=14

4. (a) A unity feedback servo driven instrument has open-loop transfer function

$$G(s) = \frac{K}{s(sT + 2)}$$

(i) Find the factor by which the gain (K) must be multiplied so that the damping ratio increases from 0·3 to 0·9.

(ii) Find the factor by which the time constant (T) must be multiplied so that the damping ratio decreases from 0·9 to 0·3.

(iii) Show that $\frac{TK_1 - 1}{TK_1 - 2} = 11 \cdot 39$ when the system overshoot reduces from 70% to 30% where K_1 and K_2 are the values of K for 70% and 30% overshoot.

(b) Using generalized error series, calculate the steady-state error of a unity feedback system having

$$G(s) = \frac{40}{s(s+15)}$$

for the following excitations :

(i) $r(t) = 8$

(ii) $r(t) = 4t + 5$

(iii) $r(t) = t^2/3 + 9$

(iv) $r(t) = 1 + 18t + 25t^2/2$ 7+7=14

5. (a) Consider a unity feedback system with forward path transfer function

$$G(s) = \frac{K(s+5)}{s^3 + ps^2 + 8s + 3}$$

has the oscillation of 3·5 rad/sec. Determine the values of $K_{marginal}$ and p. There are no poles in *RHP*.

(b) Draw root locus for the system having

$$G(s) = \frac{K(s+2)(s+4)}{(s+1)(s+3)(s+5)}$$

and find the gain K for $\xi = 0 \cdot 341$. 7+7=14

6. (a) Sketch the Nyquist plot for a system having

$$G(s)H(s) = \frac{10(1 + 0 \cdot 9s)}{s^2(0 \cdot 1s + 1)(0 \cdot 05s + 1)}$$

In addition, comment on the closed-loop stability.

(b) Sketch the Bode plot for the system

$$G(s)H(s) = \frac{Ke^{0 \cdot 2s}}{s(s+10)(1 + 0 \cdot 5s)}$$

Determine the system gain K for the gain cross-over frequency to be 4 rad/s. What is the phase margin for this value of K? 7+7=14

7. (a) The open-loop transfer function with unity feedback is given by

$$G(s) = \frac{20}{s(s+8)}$$

Design a lead compensator such that the closed-loop system satisfies the following specifications :

Static velocity error constant $= 15s^{-1}$

Phase margin = 55°

Gain margin ≥ 12 dB

(b) Find K and a for a feedback system with forward path transfer function

$$G(s) = \frac{K}{s(s+a)}$$

so that resonant peak is 3·8 and resonant frequency is 30 rad/s. Also determine the settling time and bandwidth of the system. 7+7=14

8. (a) Find the transfer function of the given state-space model :

$$\dot{x} = \begin{bmatrix} -5 & 0 & 1 \\ 1 & -4 & 0 \\ 1 & 1 & -1 \end{bmatrix} x + \begin{bmatrix} 1 & 0 \\ 0 & 2 \\ 1 & 0 \end{bmatrix} u, \; y = \begin{bmatrix} 8 & 1 & -1 \\ 0 & 1 & 0 \end{bmatrix} x$$

(b) Consider the state-space model of an LTI system with matrices

$$A = \begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix}, \; B = \begin{bmatrix} 0 \\ 8 \end{bmatrix}$$

Find the state transition matrix.

(c) Consider the LTI system

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ -5 & -9 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

Find the non-homogeneous solution if $x_1(0) = 4$, $x_2(0) = 0$ and u is a unit step function. 4+5+5=14

9. (a) Explain how linear state regulator is used for accommodation of external disturbances acting on the process.

(b) Derive the describing function of dead-zone non-linearity.

(c) Describe the different types of singular points and discuss their importance in stability analyses of non-linear system. 5+4+5=14

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