OR iii. For the given system $G(s)H(s) = \frac{5}{s(2+s)}$, design a lead compensator such that the closed loop system will satisfy the following specifications: **6**

(a) k_v=20 per sec

(b) Phase margin is at least 50

(c) Gain margin is at least 10 dB

Q.6 Attempt any two:

i. Define Controllability and Observability. **4**

ii. A system is characterized by the equation **6**

$$\frac{Y(s)}{U(s)} = \frac{20(4s+2)}{s^3 + 5s^2 + 8s + 2}$$

Find the state and output equations of the system and express them in vector matrix form. Also draw the state diagram.

OR iii. Define the ZIR and ZSR solution of state equation and explain the properties of state transition matrix. **6**

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Enrollment No......................................

Faculty of Engineering

End Sem (Odd) Examination Dec-2022

EC3CO09 Control Systems

Programme: B.Tech. Branch/Specialisation: EC

Duration: 3 Hrs. **Maximum Marks: 60**

Note: All questions are compulsory. Internal choices, if any, are indicated. Answers of Q.1 (MCQs) should be written in full instead of only a, b, c or d.

Q.1 i. With feedback ____ increases. **1**

(a) System stability (b) System gain

(c) System accuracy (d) All of these

ii. A mass M initially at rest acted upon by a force F(t) is described by- **1**

(a) $M\frac{d^2v}{dt^2} = F$ (b) $M\frac{d^2x}{dt^2} = F$

(c) $M\frac{dx}{dt} = F$ (d) $Mv = F$

iii. The transfer function of a control system is given as- **1**

$$\frac{C(s)}{R(s)} = \frac{K}{s^2 + 4s + K}$$

For this system to be critically damped, the value of gain K should be-

(a) 1 (b) 2 (c) 3 (d) 4

iv. A unity feedback control system has forward path transfer function as- **1**

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

the type and order of system is, respectively-

(a) 0, 2 (b) 0, 1 (c) 1, 2 (d) None of these

v. Which of the following is not in frequency domain? **1**

(a) Nyquist criterion (b) Bode plot

(c) Root locus plot (d) All of these

vi. If the input is removed from the system, then output must be reduced to zero. This type of stability is called- **1**

(a) Conditional stability (b) Asymptotic stability
(c) Absolute stability (d) Relative stability

vii. The transfer function of a phase-lag compensator is given by- **1**

(a) $\frac{1+s\beta T}{1+s}, \beta < 1$ (b) $\frac{1+s\beta T}{1+sT}, \beta > 1$
(c) $\frac{1+sT}{1+s\beta T}, \beta < 1$ (d) $\frac{1+sT}{1+s\beta T}, \beta > 1$

viii. Bandwidth is increased when the compensator used is- **1**

(a) Lag (b) Lead (c) Lag-Lead (d) None of these

ix. The characteristic equation of the system matrix, **1**

$A = \begin{bmatrix} 0 & 1 \\ -3 & -5 \end{bmatrix}$ is given by-

(a) $s^2 + 5s + 3 = 0$ (b) $s^2 - 3s - 5 = 0$
(c) $s^2 + 3s + 5 = 0$ (d) $s^2 + s + 2 = 0$

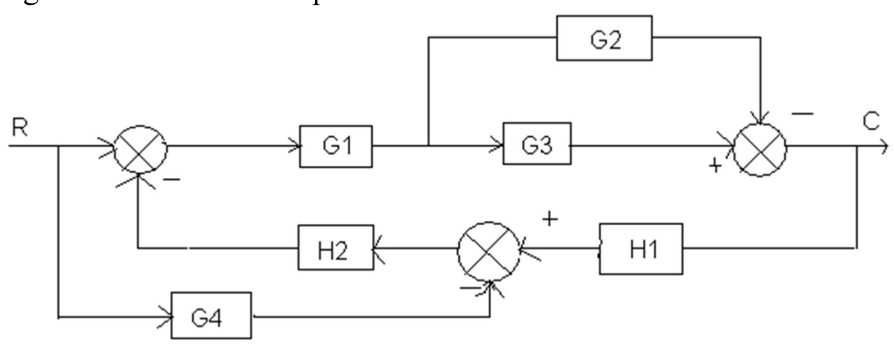
x. In the given the matrix, **1**

$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}$, the eigen values of A are-

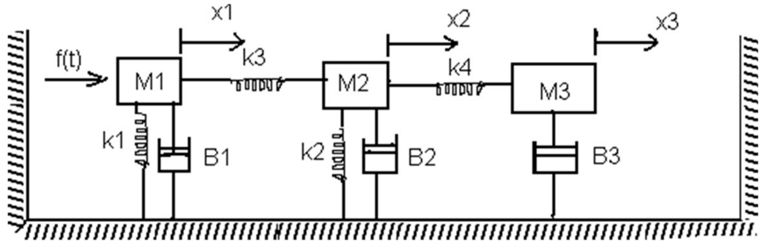
(a) –1, –2, –3 (b) –1, 2, –3
(c) 0, 0, –6 (d) –6, –11, –6

Q.2 i. Define Mason's Gain formula with an example. **4**

ii. Derive the Transfer function of the system shown in fig. using block diagram reduction techniques. **6**



OR iii. Draw F-I analogy of the following mechanical system: **6**



Q.3 i. Define asymptotic, absolute and conditional stability. **3**

ii. A unity feedback system has- **7**

$$G(s) = \frac{K(s+a)}{(s+b)^2}.$$

It is to be designed to meet following specifications:
Steady state error for a unit step = 0.1,
Damping ratio = 0.5,
Natural frequency of oscillations = √10. Find 'K', 'a' and 'b'.

OR iii. Draw the root locus of the given open loop unity feedback transfer function: **7**

$$G(s) = \frac{Ks^2}{s^2 + 6s + 100}$$

Q.4 i. Define Constant – M (Magnitude) circle. **3**

ii. Draw the Bode plot for the open loop system given below: **7**

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

Also find the Gain Margin.

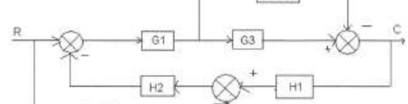
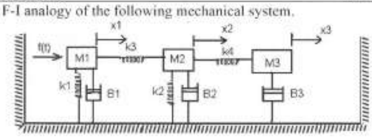
OR iii. Draw the Nyquist plot of the given open loop transfer function and find out the total No. of poles of closed loop system in RHP. **7**

$$G(s)H(s) = \frac{4s+1}{s^2(1+s)(1+2s)}$$

Q.5 i. Define phase-lead compensator. **4**

ii. Define PI and PD controllers and compare with their advantages. **6**

Marking Scheme
EC3CO09/EI3CO09 Control Systems

Q.1	i.	With feedback ___________ increases. **Answer: (D) All of the above**	1
	ii.	A mass M initially at rest acted upon by a force F(t) is described by $M\frac{d^2x}{dt^2} = F$ **Answer: (B)**	1
	iii.	The transfer function of a control system is given as $\frac{C(s)}{R(s)} = \frac{K}{s^2+4s+K}$. For this system to be critically damped, the value of gain K should be **Answer: (D) 4**	1
	iv.	A unity feedback control system has forward path transfer function as $G(s) = \frac{s^2}{s+1}$, the type and order of system is, respectively **Answer:** ~~(B) 0, 1~~ (A) 0, 2	1
	v.	Which of the following is not in frequency domain? **Answer: (C) Root locus plot**	1
	vi.	If the input is removed from the system then output must be reduced to zero. This type of stability is called **Answer: (B) Asymptotic stability.**	1
	vii.	The transfer function of a phase-lag compensator is given by **Answer: (D)** $\frac{1+sT}{1+s\beta T}, \beta > 1$	1
	viii.	Bandwidth is increased when the compensator used is **Answer: (B) Lead**	1
	ix.	The characteristic equation of the system matrix $A = \begin{bmatrix} 0 & 1 \\ -3 & -5 \end{bmatrix}$, is given by **Answer: (A)** $s^2 + 5s + 3 = 0$.	1
	x.	Given the matrix $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}$, the eigen values of A are **Answer:** ~~(C) 0, 0, -6~~ (A) -1, -2, -3	1
Q.2	i.	Define Mason's Gain formula with an example. **Marking Scheme : 1) Define formula with each terms -- 2 Marks** **2) Example -- 2 Marks**	4
	ii.	Derive the Transfer function of the system shown in fig. using block diagram reduction techniques.  **Marking Scheme:** **1) Reduction with correct steps -- 5 Marks** **2) Write answer -- 1 Mark**	6
OR	iii.	Draw F-I analogy of the following mechanical system.  **Marking Scheme:** **1) Getting equations from equivalent diagram -- 3 Marks** **2) F-I conversion and electrical diagram -- 3 Marks**	6
Q.3	i.	Define asymptotic, absolute and conditional stability. **Marking Scheme:** **Definition of each. –1 Mark**	3
	ii.	A unity feedback system has $G(s) = \frac{K(s+a)}{(s+b)^2}$. It is to be designed to meet following specifications: steady state error for a unit step = 0.1, Damping ratio = 0.5, Natural frequency of oscillations = √10. Find 'K', 'a' and 'b'. **Marking Scheme:** **1) Formula of each given terms -- 2 Marks** **2) Steps for finding values -- 3 Marks** **3) Value of 'K', 'a' and 'b' -- 2 Marks**	7
OR	iii.	Draw the Root Locus of the given open loop unity feedback transfer function:	7

		$$G(s) = \frac{Ks^2}{s^2 + 6s + 100}$$ **Marking Scheme:** **1) Pole- Zero plot -- 1 Mark** **2) Angle of asymptotes and departure -- 4 Marks** **3) Root locus plot -- 2 Marks**	
Q.4	i.	Define Constant – M (Magnitude) circle. **Marking Scheme:** **1) Definition -- 2 Marks** **2) Diagram -- 1 Marks**	3
	ii.	Draw the Bode plot for the open loop system given below: $$G(s)H(s) = \frac{1}{s(10 + s)(1 + 0.5s)}$$ Also find the Gain Margin. **Marking Scheme:** **1) Derivation for both magnitude and phase -- 2 Marks** **2) Correct plot on the graph paper -- 3 Marks** **3) Correct Gain Margin -- 2 Marks**	7
OR	iii.	Draw the Nyquist plot of the given open loop transfer function and find out the total No. of poles of closed loop system in RHP. $$G(s)H(s) = \frac{4s + 1}{s^2(1 + s)(1 + 2s)}$$ **Marking Scheme:** **1) Derivations for each section -- 4 Marks** **2) Nyquist Plot -- 2 Marks** **3) Formula for RHP poles and answer -- 1 Mark**	7
Q.5	i.	Define phase-lead compensator. **Marking Scheme:** **1) Definition and derivation -- 3 Marks** **2) Diagram -- 1 Mark**	4
	ii.	Define PI and PD controllers and compare with their advantages. **Marking Scheme:** **1) Definition of PI and PD controllers with diagram -- 4 Marks** **2) Comparison -- 2 Marks**	6
OR	iii.	For the given system $G(s)H(s) = \frac{5}{s(2+s)}$, design a lead compensator such that the closed loop system will satisfy the following specifications: 1) k_v=20 per sec, 2) Phase margin is at least 50 and 3) Gain margin is at least 10 dB **Marking Scheme:** **1) Correct formulas and steps -- 4 Mark** **2) Correct answer -- 2 Marks**	6
Q.6		Attempt any two:	
	i.	Define Controllability and Observability. **Marking Scheme:** **1) Correct definitions of each -- 4 Marks**	4
	ii.	A system is characterized by the equation $$\frac{Y(s)}{U(s)} = \frac{20(4s + 2)}{s^3 + 5s^2 + 8s + 2}$$ Find the state and output equations of the system and express them in vector matrix form. Also draw the state diagram. **Marking Scheme:** **1) Derivation for state and output equation -- 4 Marks** **2) State diagram -- 2 Marks**	6
	iii.	Define the ZIR and ZSR solution of state equation and also explain the properties of state transition matrix. **Marking Scheme:** **1) Define and derive ZIR -- 2 Marks** **2) Define and derive ZSR -- 2 Marks** **3) Properties of state transition matrix -- 2 Marks**	6