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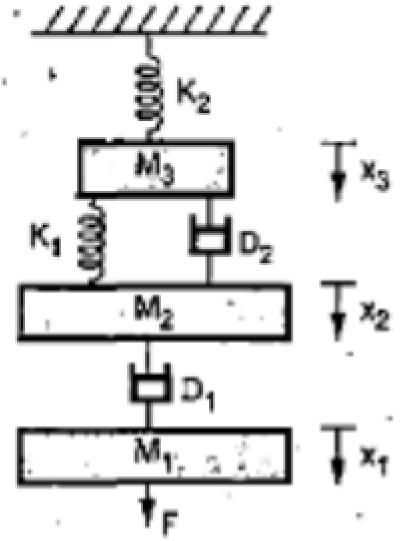
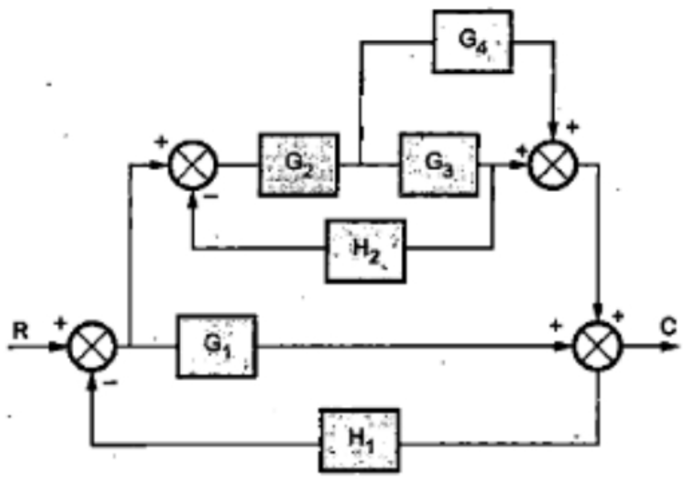
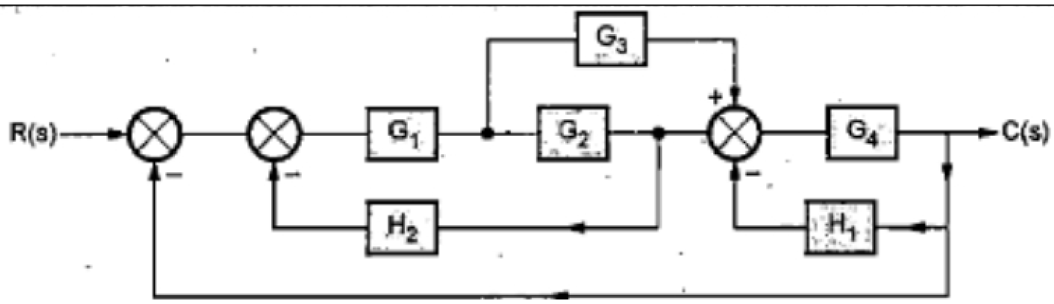
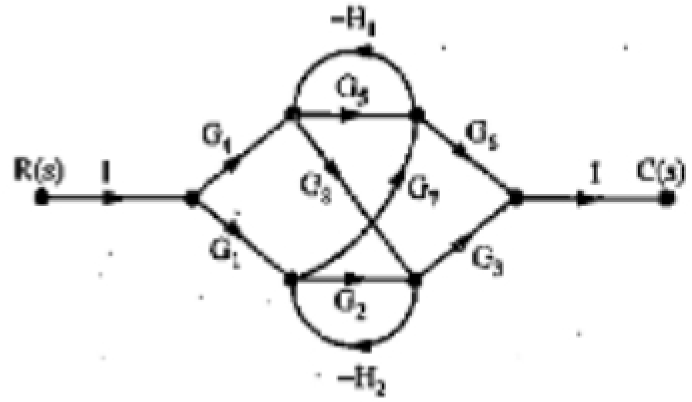
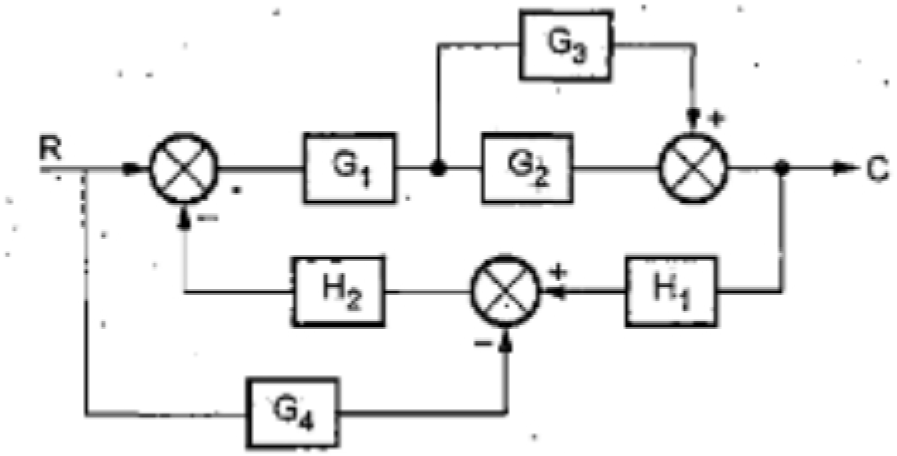
CMR INSTITUTE OF TECHNOLOGY, BENGALURU.

Internal Assessment Test 1 –Nov. 2021

Sub:	Control Engineering			Sub Code:	18ME71/17 ME73/15M E73	Branch:	Mech
Date:	15.11.21	Duration:	90 min's	Max Marks: 50	Sem/Sec:	VII/A&B	OBE

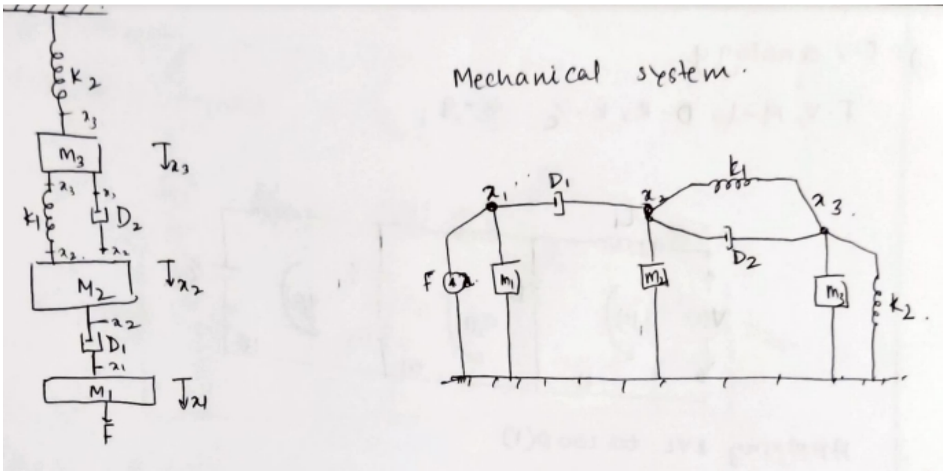
	Answer All the Questions	MARKS	CO	RBT
1	 Draw equivalent mechanical system of the given system. Hence write the set of equilibrium equations for it and obtain electrical analogous circuits using: (i) FV analogy (ii) FI analogy	[10]	CO2	L2
2	 Reduce the given block diagram to its simplest form and find its transfer function.	[10]	CO4	L2
3	 Reduce the given block diagram to its canonical form and hence find its transfer function.	[10]	CO4	L2

4.	 Using Mason's Gain Formula, find the gain of the given system.	[10]	CO4	L2
5.	 Draw signal flow graph for the given block diagram and hence find transfer function using Mason's Fain Formula.	[10]	CO4	L2

Faculty Signature CCI Signature HOD Signature

18ME71/17ME73/15ME73
Control Engineering
IAT1 Solution

1.



At node x_1

$$F(t) = M_1\frac{d^2x_1}{dt^2} + D_1\frac{d}{dt}(x_1 - x_2).$$

$$F(s) = M_1 S^2 X_1(s) + D_1 S(X_1(s) - X_2(s)).$$

At node x_2

$$0 = M_2\frac{d^2x_2}{dt^2} + D_1\frac{d}{dt}(x_2 - x_1) + D_2\frac{d}{dt}(x_2 - x_3) + K_1(x_2 - x_3).$$

$$0 = M_2 S^2 X_2 + D_2 S(X_2 - X_1) + D_2 S(X_2 - X_3) + k_1(X_2 - X_3).$$

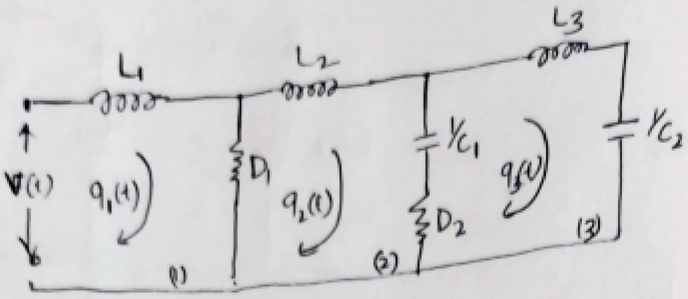
At node x_3.

$$0 = M_3\frac{d^2x_3}{dt^2} + D_2\frac{d}{dt}(x_3 - x_2) + k_1(x_3 - x_2) + k_2 x_3.$$

$$0 = M_3 S^2 X_3 + D_2 S(X_3 - X_2) + k_1(X_3 - X_2) + k_2 X_3.$$

F-V analogy.

F-V, M-L, D-R, K-$1/C$, x-q.



Applying KVL to loop(1)

$$v(t) = L_1 \frac{d^2 q_1(t)}{dt^2} + R_1 \frac{d}{dt}\left(q_1(t) - q_2(t)\right)$$

$$V(s) = L_1 s^2 Q(s) + R_1 s\left(Q_1(s) - Q_2(s)\right).$$

Applying KVL to loop(1)

$$v(t) = L_1 \frac{d^2 q_1(t)}{dt^2} + R_1 \frac{d}{dt}(q_1(t) - q_2(t))$$

$$V(s) = L_1 s^2 Q(s) + R_1 s(Q_1(s) - Q_2(s)).$$

Applying KVL to loop(2).

$$0 = L_2 \frac{d^2 q_2(t)}{dt^2} + R_1 \frac{d}{dt}(q_2(t) - q_1(t)) + R_2 \frac{d}{dt}(q_2(t) - q_3(t)) +$$

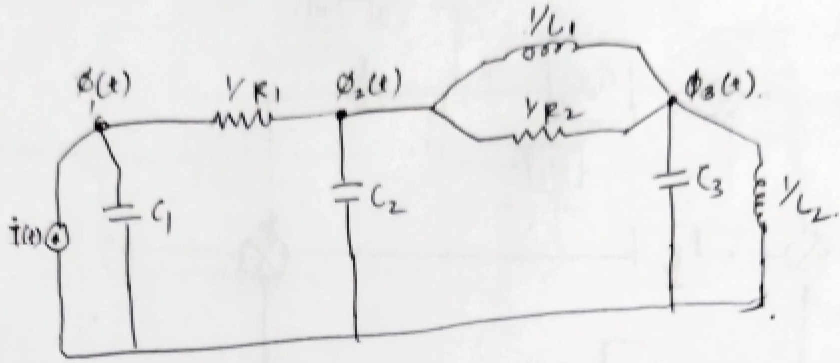
$$\frac{1}{C_1}(q_2(t) - q_3(t))$$

Applying KVL to loop(3)

$$0 = M_3 \frac{d^2 q_3(t)}{dt^2} + R_2 \frac{d}{dt}(q_3(t) - q_2(t)) + \frac{1}{C_1}(q_3(t) - q_2(t)) + \frac{1}{C_2} q_3(t)$$

F-I analogy

F-I, M-C, D-1/R, K-1/L, x-φ

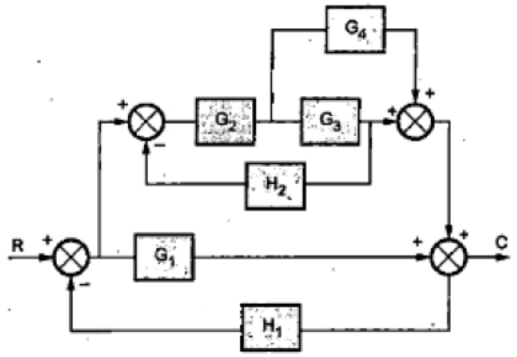


$$i(t) = C_1 \frac{d^2\phi_1(t)}{dt^2} + \frac{1}{R_1}\frac{d}{dt}\left(\phi_1(t) - \phi_2(t)\right).$$

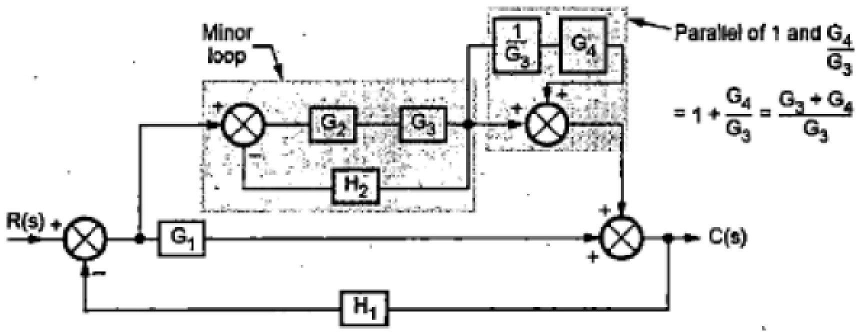
$$0 = C_2 \frac{d^2\phi_2(t)}{dt^2} + \frac{1}{R_1}\frac{d}{dt}\left(\phi_2(t) - \phi_1(t)\right) + \frac{1}{R_2}\frac{d}{dt}\left(\phi_2(t) - \phi_3(t)\right) + \frac{1}{L_1}\left(\phi_2(t) - \phi_3(t)\right).$$

$$0 = C_3 \frac{d^2\phi_3(t)}{dt^2} + \frac{1}{R_2}\frac{d}{dt}\left(\phi_3(t) - \phi_2(t)\right) + \frac{1}{L_1}\left(\phi_3(t) - \phi_2(t)\right) + \frac{1}{L_2}\phi_3(t).$$

2.



Shifting take off point of G_4 after G_3 we get,



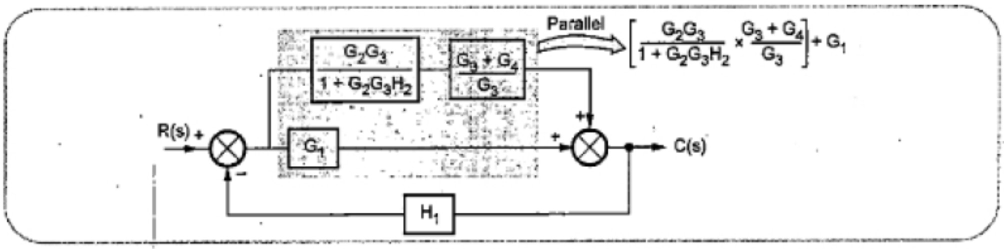


Fig. 5.3.36 (b)

$$\frac{C(s)}{R(s)} = \frac{\dfrac{G_1(1+G_2G_3H_2)+G_2(G_3+G_4)}{1+G_2G_3H_2}}{1+\dfrac{G_1(1+G_2G_3H_2)+G_2(G_3+G_4)}{1+G_2G_3H_2}\times H_1}$$

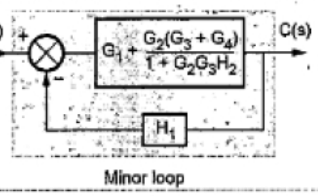
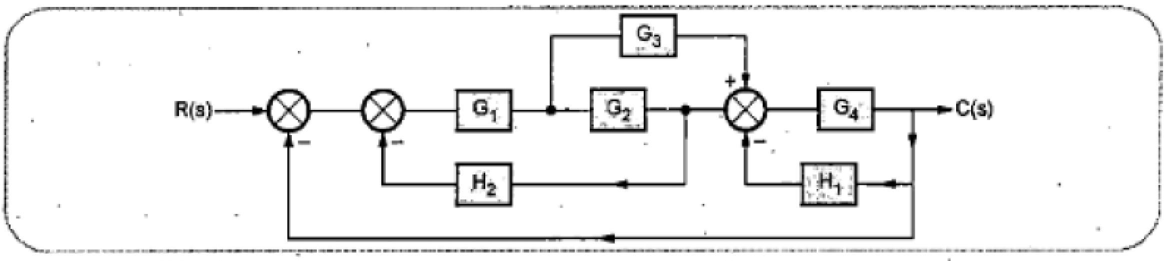


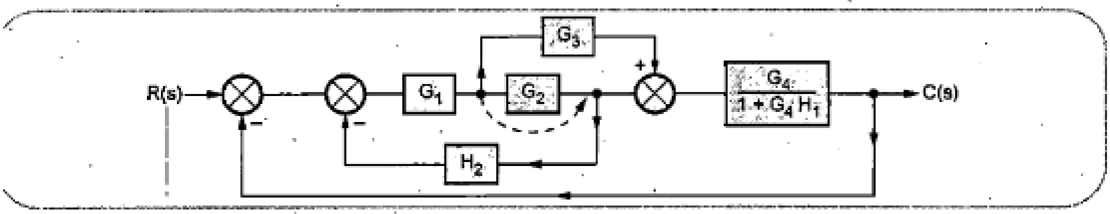
Fig. 5.3.36 (c)

$$\therefore \quad \frac{C(s)}{R(s)} = \frac{G_1+G_1G_2G_3H_2+G_2G_3+G_2G_4}{1+G_2G_3H_2+G_1H_1+G_1G_2G_3H_2H_1+G_2G_3H_1+G_2G_4H_1}$$

3.



G_4 and H_1 forms minor loop.



Shift take off point of G_3 after the block G_2.

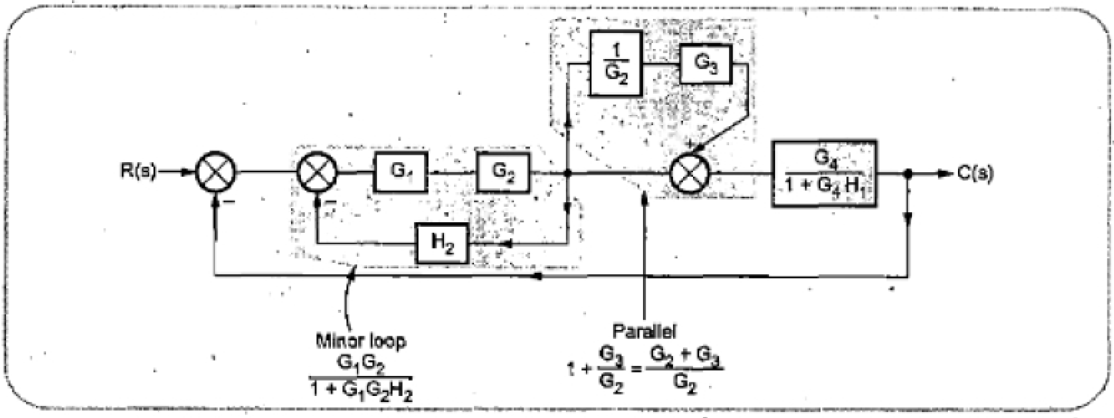


Fig. 6.3.37 (b)

$$\therefore \quad \frac{C(s)}{R(s)} = \frac{\dfrac{G_1G_4(G_2+G_3)}{(1+G_1G_2H_2)(1+G_4H_1)}}{1+\dfrac{G_1G_4(G_2+G_3)}{(1+G_1G_2H_2)(1+G_4H_1)}}$$

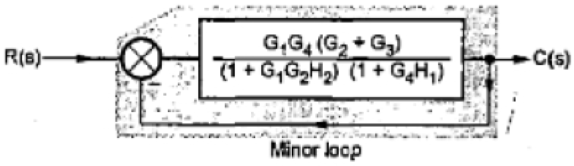
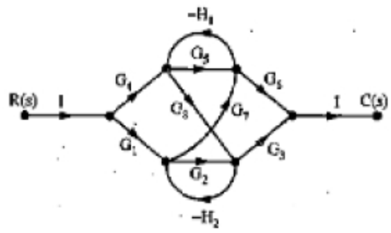


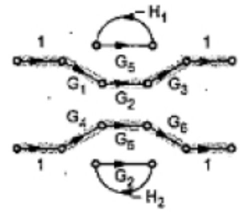
Fig. 5.3.37 (d)

$$\frac{C(s)}{R(s)} = \frac{G_1G_4(G_2+G_3)}{1+G_1G_2H_2+G_4H_1+G_1G_2G_4H_1H_2+G_1G_2G_4+G_1G_3G_4}$$

4.



Sol : The number of forward paths are K = 6.



The forward path gains are,

$$T_1 = G_1G_2G_3, \qquad T_2 = G_4G_5G_6$$

$$T_3 = G_1G_7G_6, \qquad T_4 = G_4G_8G_3$$

$$T_5 = G_4G_8(-H_2)G_7G_6, \; T_6 = G_1G_7(-H_1)G_8G_3$$

The feedback loop gains are,

$$L_1 = -G_5H_1, \; L_2 = -G_2H_2, \; L_3 = +G_7H_1G_8H_2$$

The two nontouching loops are $L_1 L_2$.

$\therefore \quad L_1L_2 = +G_2G_5H_1H_2$

$\therefore \quad \Delta = 1-[L_1+L_2+L_3]+[L_1L_2] = 1+G_5H_1+G_2H_2-G_7G_8H_1H_2+G_2G_5H_1H_2$

For T_1, L_1 is nontouching.

$\therefore \quad \Delta_1 = 1-L_1 = 1+G_5H_1$

For T_2, L_2 is nontouching.

$\therefore \quad \Delta_2 = 1-L_2 = 1+G_2H_2$

For T_3 to T_6 all loops are touching to all forward paths.

$\therefore \quad \Delta_3 = \Delta_4 = \Delta_5 = \Delta_6 = 1$

$$\therefore \quad \text{Gain} = \frac{\Sigma T_K \Delta_K}{\Delta} = \frac{T_1\Delta_1+T_2\Delta_2+T_3\Delta_3+T_4\Delta_4+T_5\Delta_5+T_6\Delta_6}{\Delta}$$

$$\therefore \quad \boxed{\text{Gain} = \frac{G_1G_2G_3(1+G_5H_1)+G_4G_5G_6(1+G_2H_2)+ G_1G_7G_6+G_4G_8G_3-G_4G_8G_7G_6H_2-G_1G_3G_7G_8H_1}{1+G_5H_1+G_2H_2-G_7G_8H_1H_2+G_2G_5H_1H_2}}$$ ... **Ans.**

5.

Sol. : Representing each summing and take off point by a separate node, the signal flow graph is as shown in the Fig. 6.5.6 (a).

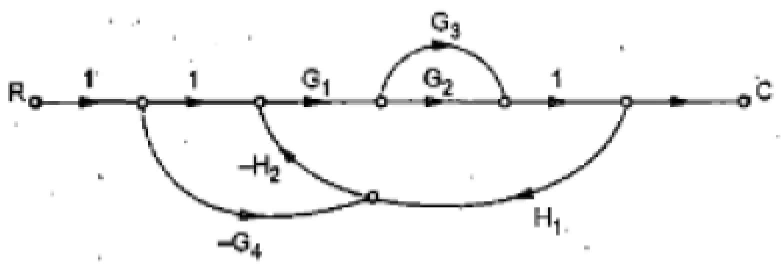


Fig. 6.5.6

Forward path gains are,

$$T_1 = G_1G_2,$$

$$T_2 = G_1G_3,$$

$$T_3 = +G_4H_2G_1G_2$$

$$T_4 = G_4H_2G_1G_3$$

The feedback loop gains are,

$$L_1 = -G_1G_2H_1H_2,$$

$$L_2 = -G_1G_3H_1H_2$$

No combination of non-touching loops.

$$\therefore \quad \Delta = 1-[L_1+L_2]$$

All loops are touching to all the forward paths hence $\Delta_1 = \Delta_2 = \Delta_3 = \Delta_4 = 1$

$$\frac{C}{R} = \frac{T_1\Delta_1 + T_2\Delta_2 + T_3\Delta_3 + T_4\Delta_4}{\Delta}$$

$$\frac{C}{R} = \boxed{\frac{G_1G_2 + G_1G_3 + G_1G_2G_4H_2 + G_1G_3G_4H_2}{1+G_1G_2H_1H_2 + G_1G_3H_1H_2}}$$