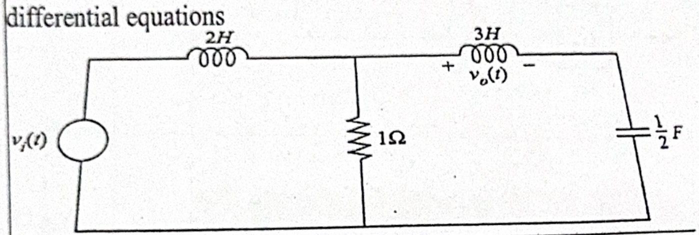
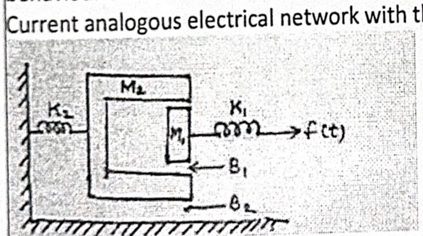
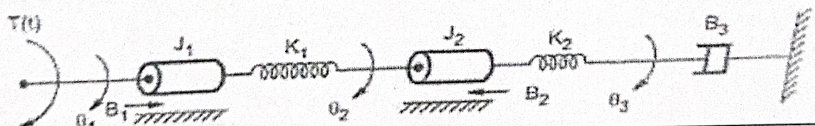
CMR
INSTITUTE OF
TECHNOLOGY

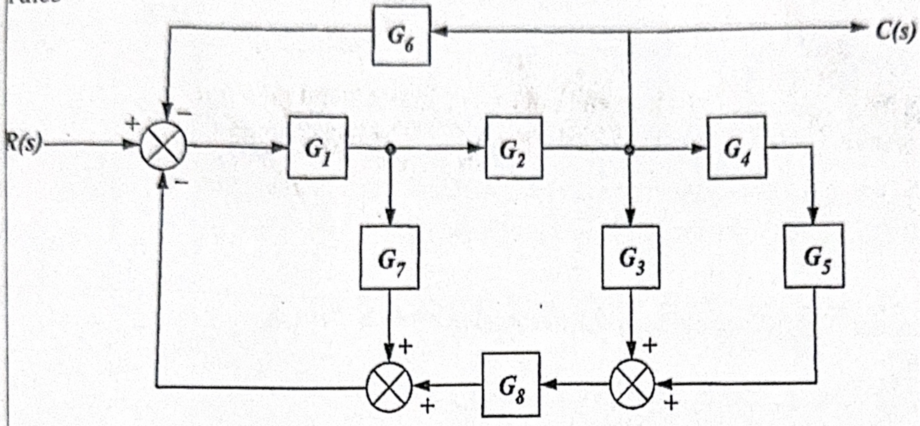
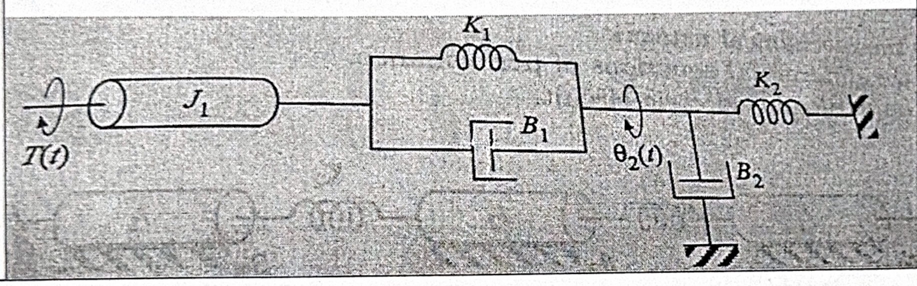
USN | | | | | | | | | | |

Internal Assesment Test - I

Sub:	Control Systems							Code:	BEC403
Date:	27/ 03/ 2025	Duration:	90 mins	Max Marks:	50	Sem:	4^{th}	Branch:	ECE
Answer Any FIVE FULL Questions									

		Marks	OBE CO	OBE RBT
1.	a) Define Control System? Compare open loop and closed loop systems and give two practical examples of each. (6M) b) Illustrate how to perform the following in connection with block diagram reduction rules. I) shifting summing point after the block II) Shifting take off point before the block (4M)	[10]	CO1	L2
2.	Find the transfer function Vo(s)/Vi(s) of the given electrical network by writing differential equations  	[10]	CO1	L3
3.	Draw the equivalent mechanical system and write the differential equations governing the behaviour of the mechanical system given below. Also Find the Force-Voltage and Force-Current analogous electrical network with their differential equations.  	[10]	CO1	L3
4	Draw the equivalent mechanical system and write the differential equations governing the behaviour of the mechanical system given below. Also Find the Torque-Voltage and Torque-Current analogous electrical network with their differential equations.  	[10]	CO1	L3
5	The performance equations of a controlled system are given by the following set of linear algebraic equations: (i) Draw the signal flow graph. (ii) Find the overall transfer function I_0/V_1 using Mason's Gain Formula. $I_1=\frac{V1-V2}{R1}$, $V_2=(I1-I0)2R_1$, $I_2=\frac{V1-V3}{R1}$, $V_3=(I2+I0)\ R_1$	[10]	CO1	L3

P.T.O

6	Obtain the transfer function of the given diagram by using Block Diagram reduction rules 	[10]	CO1	L3
7.	Find the transfer function $\theta_2(s)/F(s)$ 	[10]	CO1	L3

CI

CCI

HOD

IAT I Control Systems Question Paper Solutions

- Dr. Rasmitha. A

1

1. a) Def and Comparison with examples.

(Refer class notes)

Def – 2M

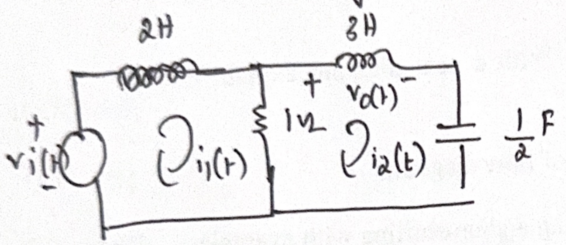
Comparison and Examples – 4M

b) i) shifting summing point before the block — 2M

ii) shifting take off point after the block — 2M

(Refer class notes)

2.



Two loops — so Assume two Currents

By writing KVL in the first loop

$$-v_i(t) + 2 \cdot \frac{di(t)}{dt} + 1\left(i_1(t) - i_2(t)\right) = 0$$

$$v_i(t) = 2 \cdot \frac{di_1(t)}{dt} + i_1(t) - i_2(t)$$

apply L.T on both sides

$$V_i(s) = 2s\, i_1(s) + i_1(s) - i_2(s)$$

$$\boxed{V_i(s) = (2s+1)\, i_1(s) - i_2(s)} \longrightarrow 1$$

By writing KVL in second loop

$$3 \cdot \frac{di_2(t)}{dt} + \frac{1}{\frac{1}{2}}\int i_2(t) + 1\left(i_2(t) - i_1(s)\right) = 0$$

Apply L.T on both sides

$$3s\, i_2(s) + \frac{2}{s} i_2(s) + i_2(s) - i_1(s) = 0$$

$$\left(3s + \frac{2}{s} + 1\right) i_2(s) = i_1(s)$$

By taking LCM

②'

$$\boxed{\left(\frac{3s^2+s+2}{s}\right) i_2(s) = i_1(s)} \longrightarrow ②'$$

$$V_o(t) = 3 \cdot \frac{di_2(t)}{dt}$$

$$\boxed{V_o(s) = 3s\, i_2(s)} \longrightarrow ③$$

Since $V_o(s)$ is interms of $i_2(s)$ let us write ① equation also in $i_2(s)$ to find the ratio $\frac{V_o(s)}{V_i(s)}$.

From ② substitute $i_1(s)$ in equ ①

$$\therefore \quad V_i(s) = (2s+1)\, i_1(s) - i_2(s)$$

$$V_i(s) = (2s+1)\left[\left(\frac{3s^2+s+2}{s}\right) i_2(s)\right] - i_2(s)$$

$$V_i(s) = \frac{(6s^3+2s^2+4s+3s^2+s+2)\, i_2(s) - s\, i_2(s)}{s}$$

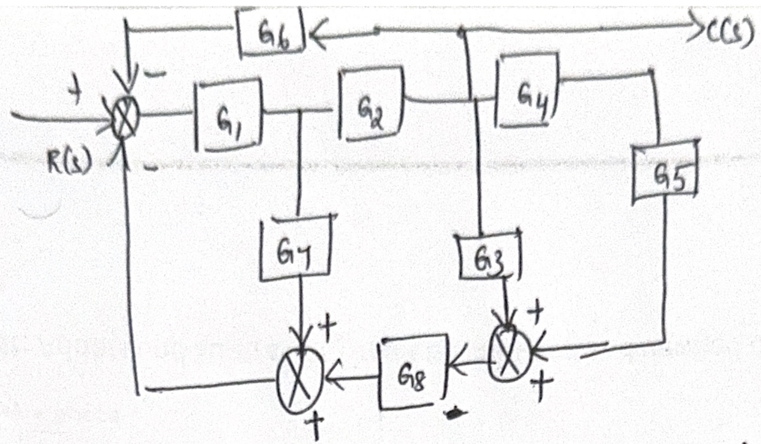
$$V_i(s) = \frac{(6s^3+5s^2+4s+\cancel{s}+2-\cancel{s})\, i_2(s)}{s}$$

$$\boxed{V_i(s) = \frac{(6s^3+5s^2+4s+2)\, i_2(s)}{s.}} \longrightarrow ④$$

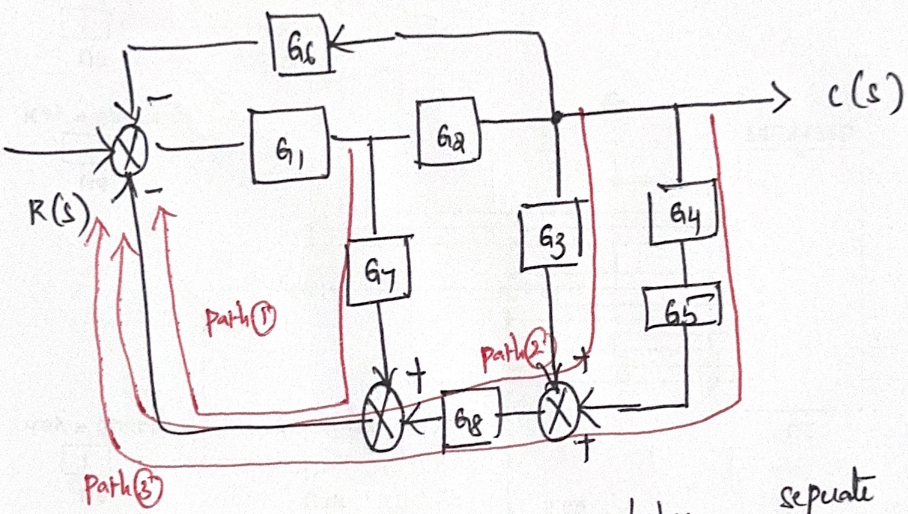
$$\frac{V_o(s)}{V_i(s)} = \frac{3s\, \cancel{i_2(s)}}{\frac{(6s^3+5s^2+4s+2)}{s}\, \cancel{i_2(s)}}$$

$$\boxed{\frac{V_o(s)}{V_i(s)} = \frac{3s^2}{6s^3+5s^2+4s+2}}$$

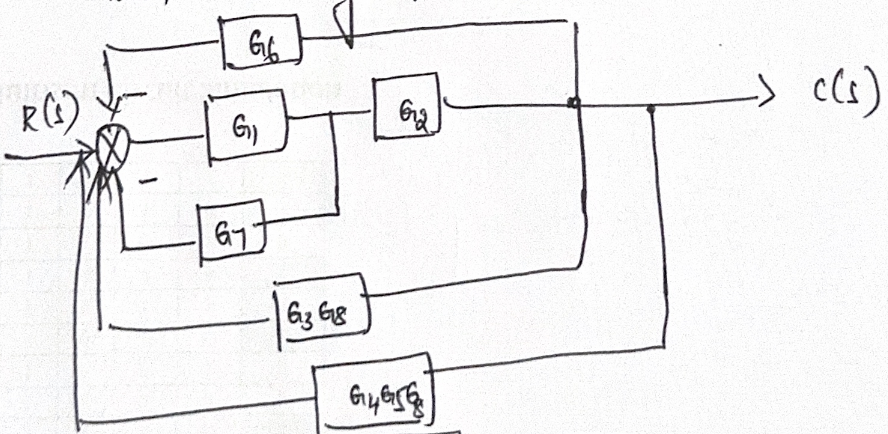
(b)

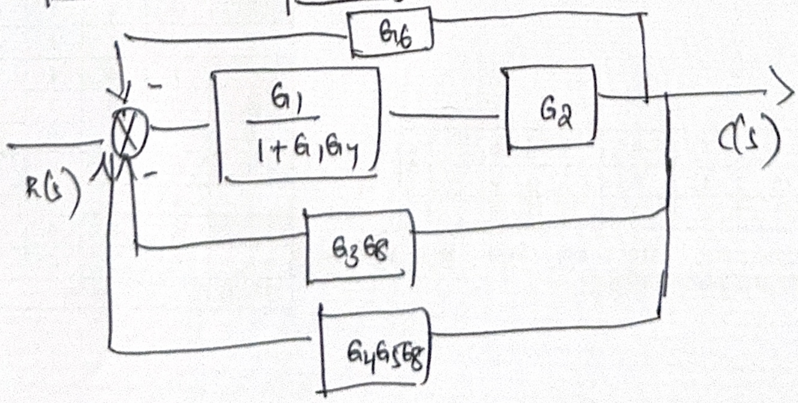


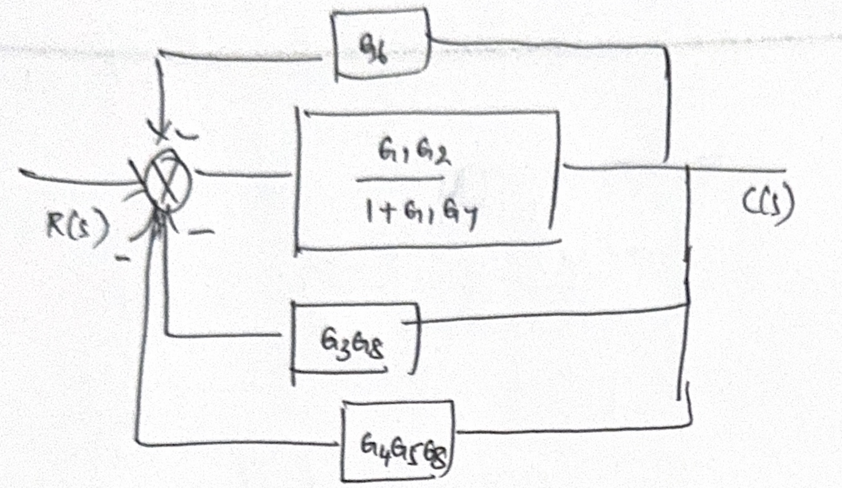
Redraw the diagram (always start from the input to output)

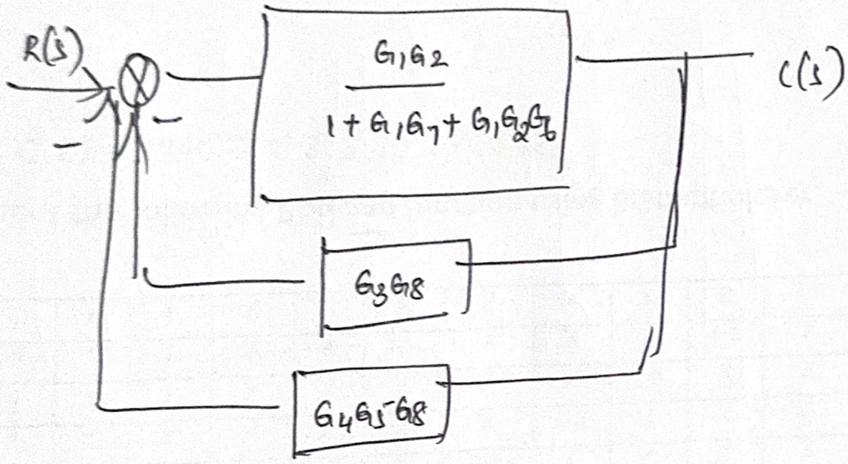


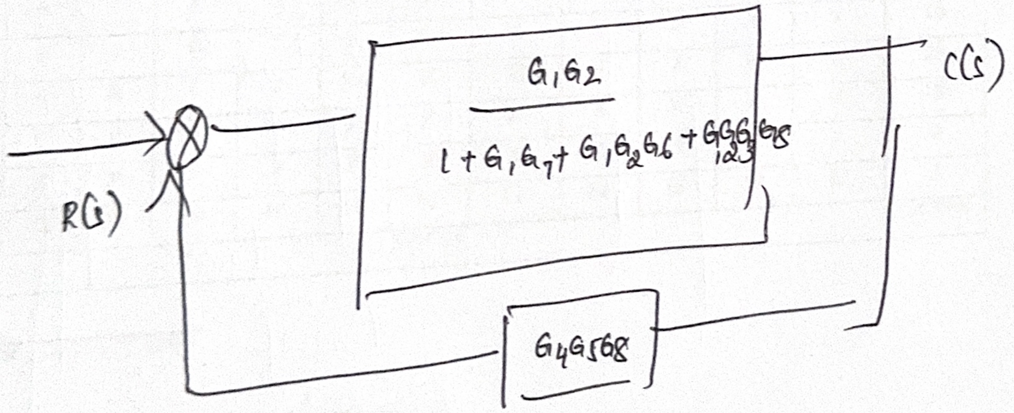
when Summing points are below, separate the paths.





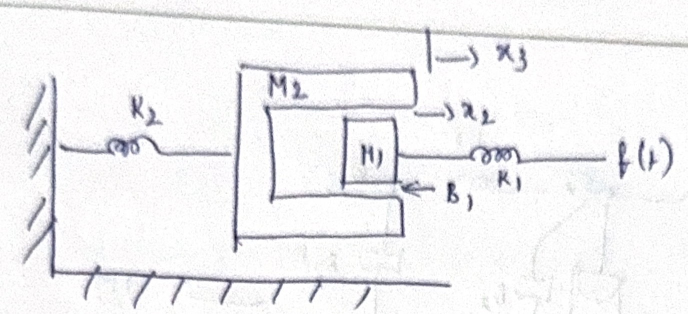


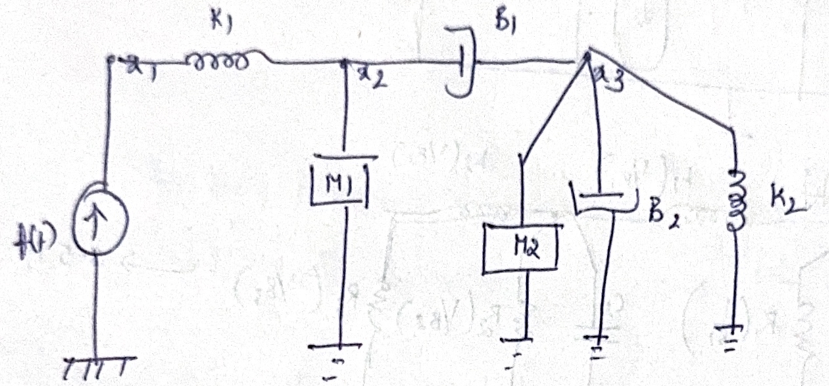




$$\boxed{\frac{C(s)}{R(s)} = \frac{G_1G_2}{1+G_1G_7+G_1G_2G_6+G_1G_2G_3G_8+G_1G_2G_4G_5G_8}}$$

5





→ 1 M

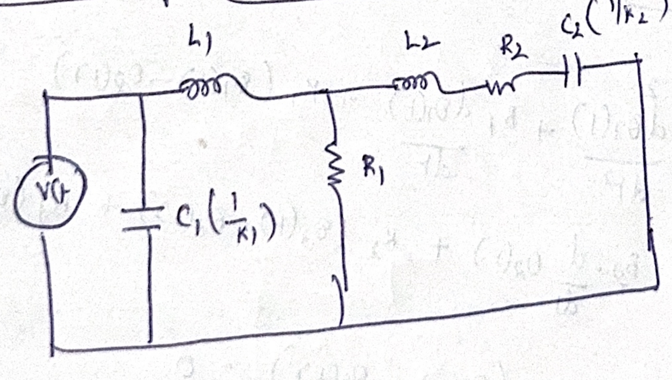
$$f(t) = K_1(x_1 - x_2)$$

$$M_1 \frac{d^2x_2(t)}{dt^2} + K_1(x_2 - x_1) + B_1 \frac{d}{dt}(x_2 - x_3) = 0$$

$$M_2 \cdot \frac{d^2x_3}{dt^2} + B_2 \cdot \frac{dx_3}{dt} + K_2 x_3(t) + B_1 \cdot \frac{d}{dt}(x_3 - x_2) = 0$$

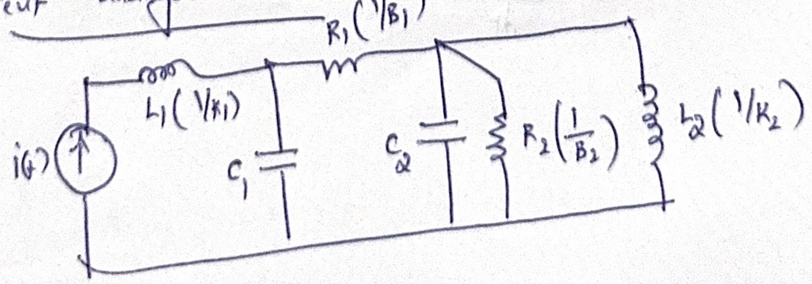
} 2M

Force - Voltage analogous n/w



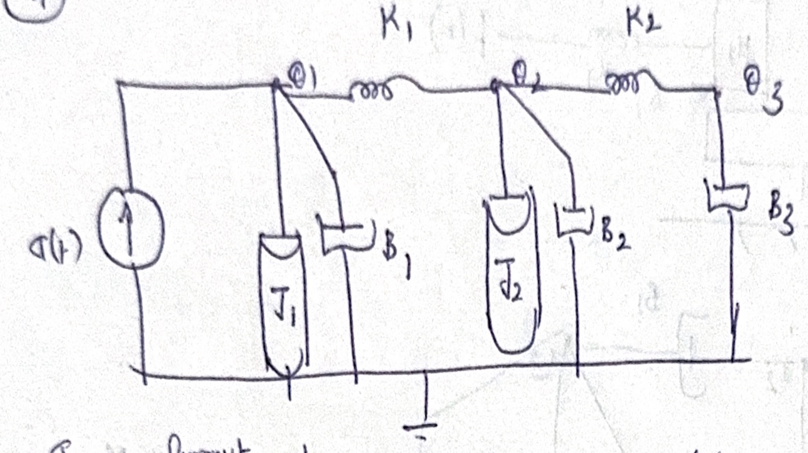
— 3.5 M

Force - Current analogous n/w



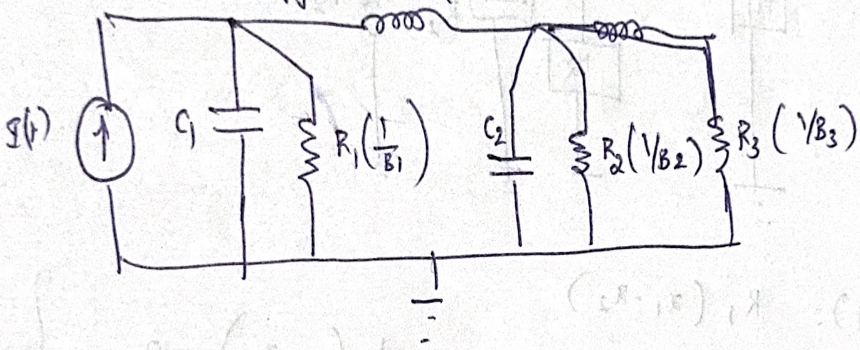
— 3.5 M

4



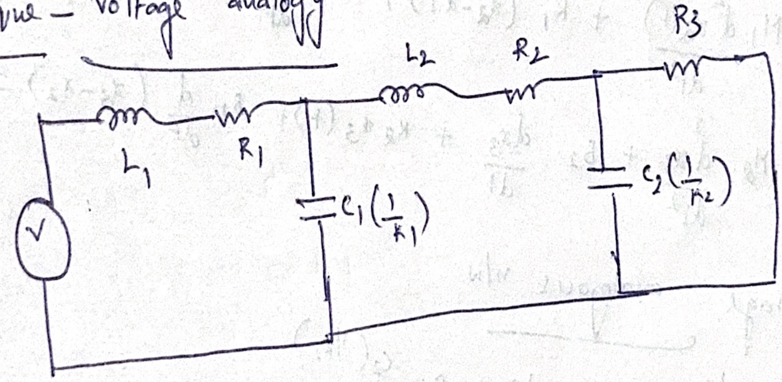
⟶ 1M

Torque – Current analogy



⟶ 3.5M

Torque – Voltage analogy



⟶ 3.5M

$$\left.\begin{aligned}
\tau(t) &= J_1 \frac{d^2\theta_1(t)}{dt^2} + B_1 \frac{d\theta_1(t)}{dt} + K_1\left(\theta_1(t)-\theta_2(t)\right) \\
& J_2 \cdot \frac{d^2\theta_2(t)}{dt^2} + B_2 \cdot \frac{d}{dt}\theta_2(t) + K_2\left(\theta_3(t)-\theta_2(t)\right) + K_1\left(\theta_2(t)-\theta_1(t)\right) = 0 \\
& B_3 \frac{d\theta_3(t)}{dt} + K_2\left(\theta_3(t)-\theta_2(t)\right) = 0
\end{aligned}\right\} \text{2M}$$

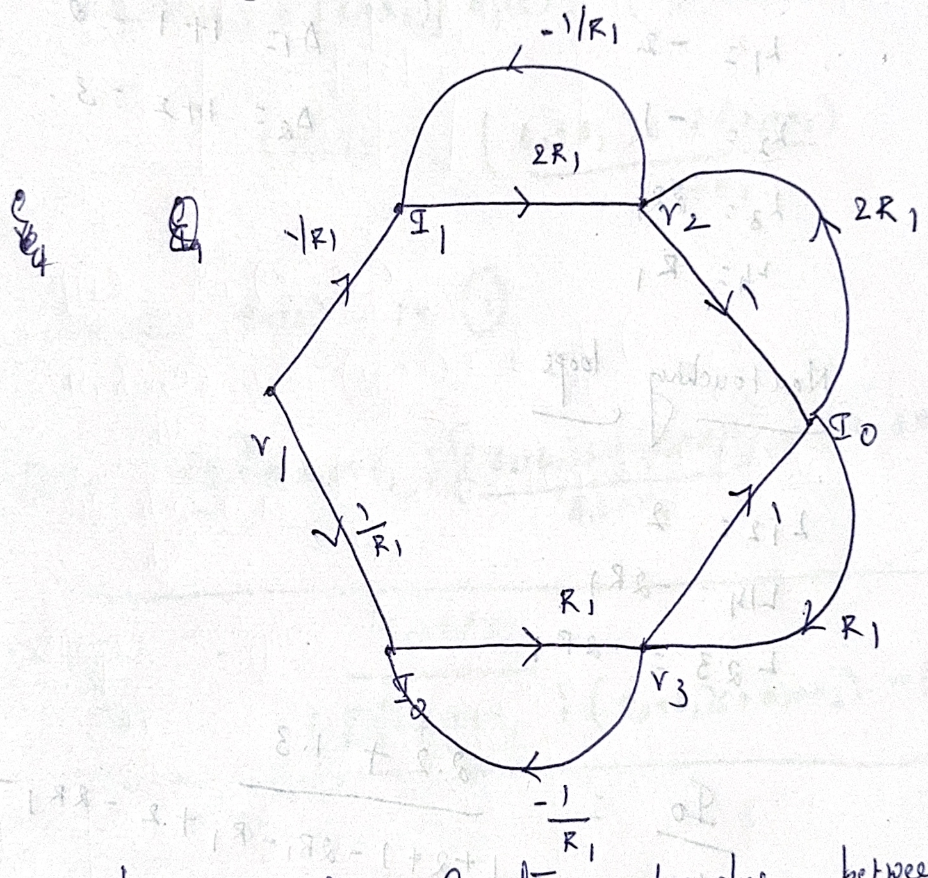
(5)

$$I_1 = \frac{V_1 - V_2}{R_1}$$

$$V_2 = (I_1 - I_0)\, 2R_1$$

$$I_2 = \frac{V_1 - V_3}{R_1}$$

$$V_3 = (I_2 + I_0)\, R_1$$



As there are no connecting branches between the nodes V_2 & I_0 and V_3 and I_0. Assume unity gain.

So the equation is $\boxed{I_0 = V_2 + V_3.}$

No of forward paths $K = 2$

$P_1 = 2$

$P_2 = 1$

No of loops

$L_1 = -2$

$L_2 = -1$

$L_3 = 2R_1$

$L_4 = R_1$

$\Delta_1 = 1 + 1 = 2$

$\Delta_2 = 1 + 2 = 3$.

Non touching loops

$L_{12} = 2$

$L_{14} = -2R_1$

$L_{23} = -2R_1$

$$\frac{I_0}{V_1} = \frac{2.2 + 1.3}{1 + 2 + 1 - 2R_1 - R_1 + 2 - 2R_1 - 2R_1}$$

$$\boxed{\frac{I_0}{V_1} = \frac{7}{6 - 7R_1}}$$

CMR

(7) $T(t) = J_1 \frac{d^2\theta_1(t)}{dt^2} + B_1\left(\frac{d\theta_1(t)}{dt} - \frac{d\theta_2(t)}{dt}\right) + K_1\left(\theta_1(t) - \theta_2(t)\right)$

$T(s) = (J_1 s^2 + B_1 s + K_1)\,\theta_1(s) - (B_1 s + K_1)\,\theta_2(s) \longrightarrow (1)$

$B_2 \cdot \frac{d\theta_2(t)}{dt} + K_2\theta_2(t) + B_1\frac{d}{dt}(\theta_2(t) - \theta_1(t)) + K_1(\theta_2(t) - \theta_1(t)) = 0$

$\left[(B_2 + B_1)s + (K_1 + K_2)\right]\theta_2(s) = (B_1 s + K_1)\,\theta_1(s).$

$\theta_1(s) = \frac{(B_2 + B_1)s + (K_1 + K_2)}{B_1 s + K_1}.$

Substitute $\theta_1(s)$ in (1)

$T(s) = (J_1 s^2 + B_1 s + K_1)\left[\frac{(B_2 + B_1)s + (K_1 + K_2)}{B_1 s + K_1}\right] - (B_1 s + K_1)\,\theta_2(s)$

$$\boxed{\frac{\theta_2(s)}{T(s)} = \frac{B_1 s + K_1}{(J_1 s^2 + B_1 s + K_1)(B_2 + B_1)s + K_1 + K_2) - (B_1 s + K_1)^2}}$$