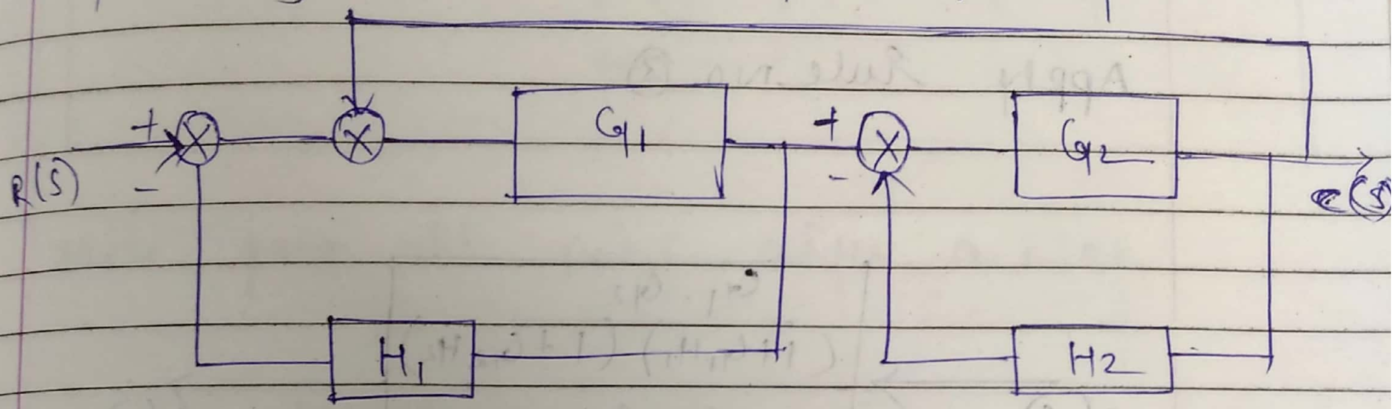
Date ....
Page ....

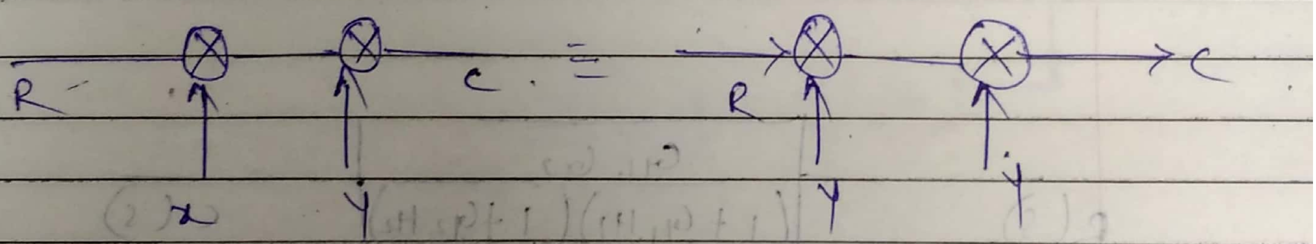
1

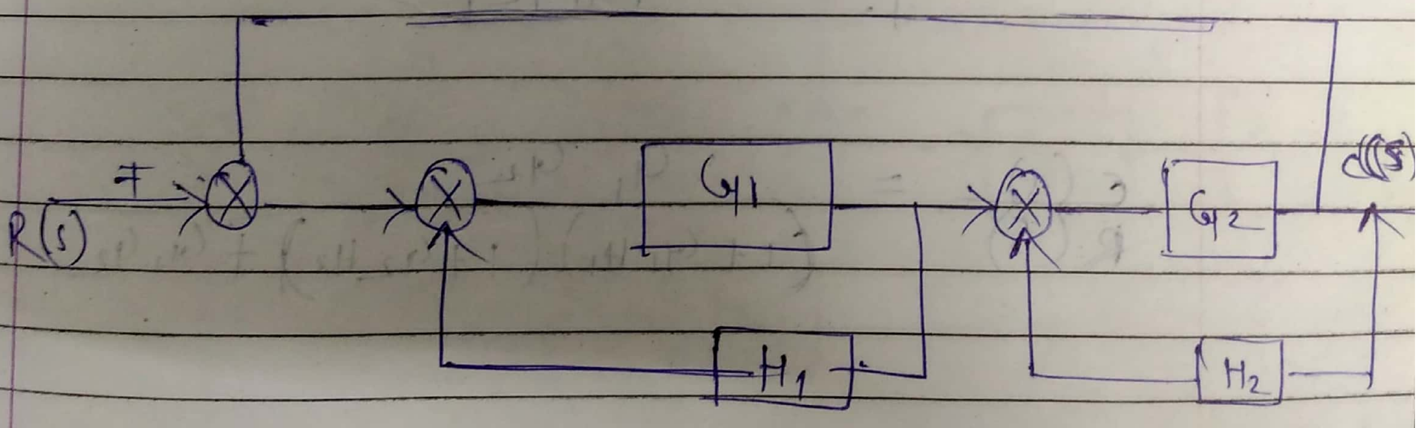
W-2015
7 marks

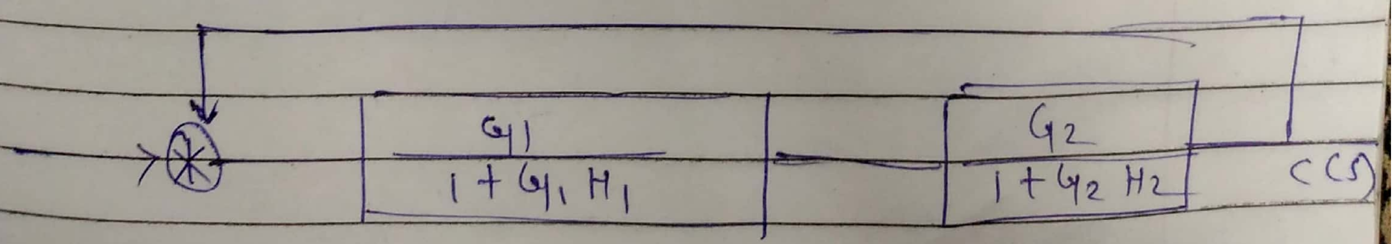
Q- Find the value of transfer function $\frac{C(S)}{R(S)}$ using block reduction technique by using block reduction techniques.

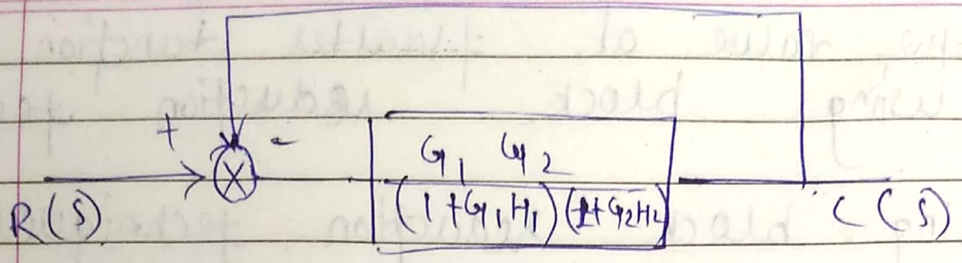


Apply rule No. (4)

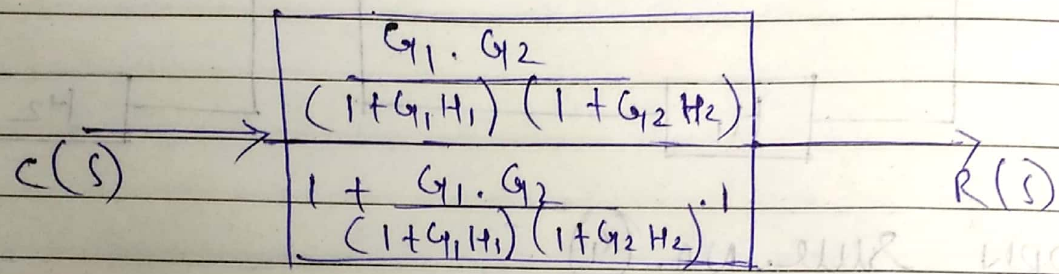


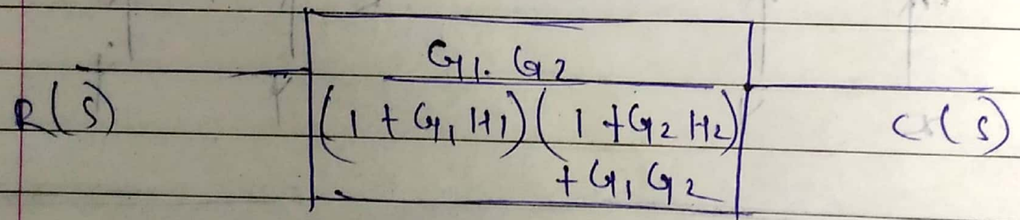






Apply Rule No. 3



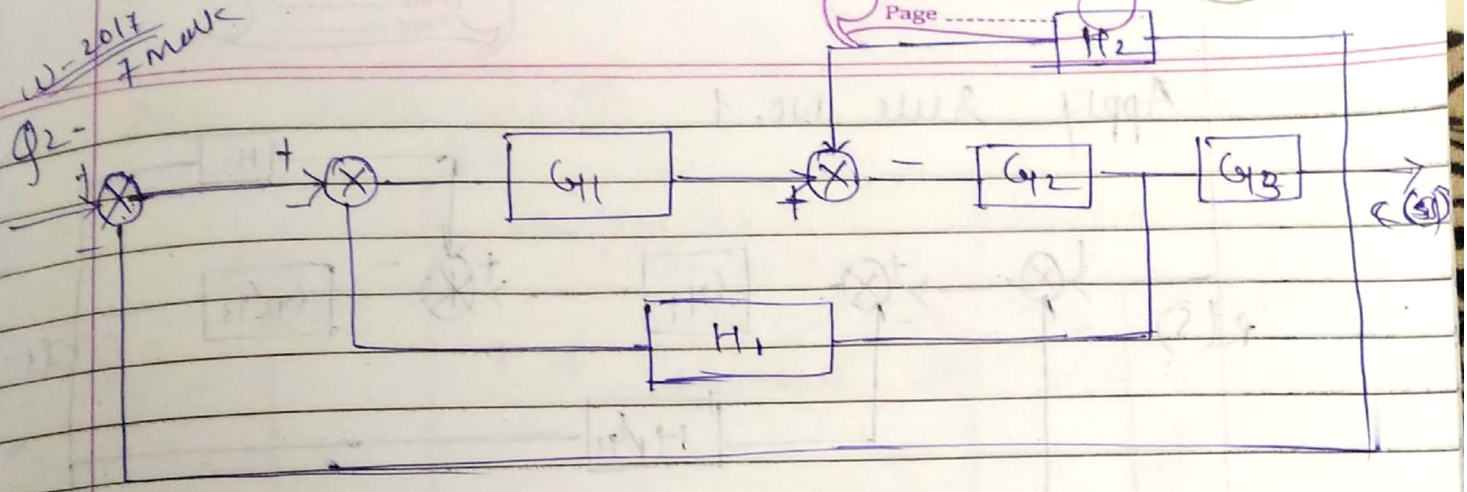


$$\frac{C(s)}{R(s)} = \frac{G_1 G_2}{(1+G_1H_1)(1+G_2H_2)+G_1G_2}$$

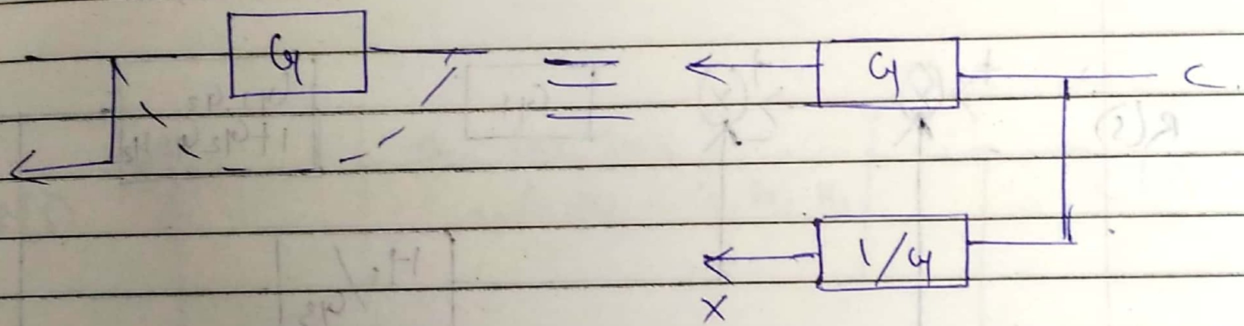
Date ....
Page ....

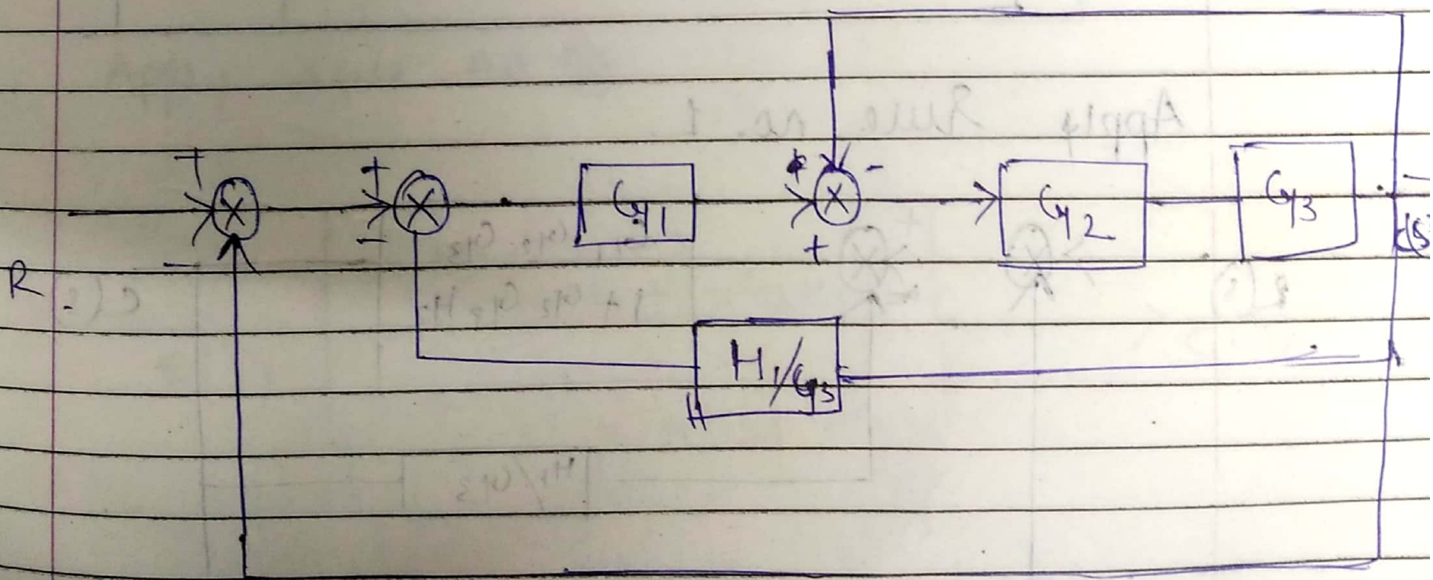
W-2017
7 Mark

Q2-

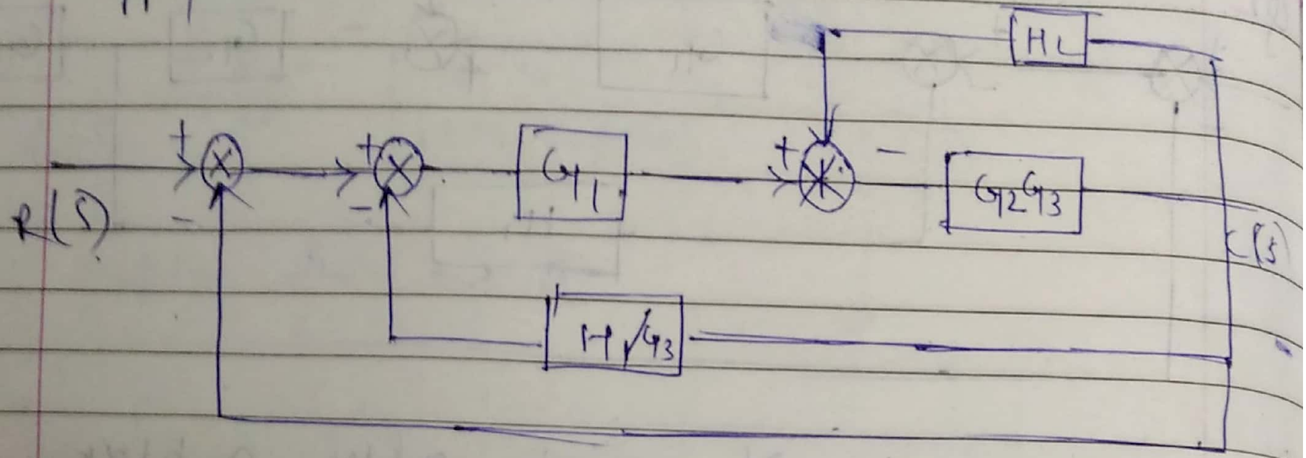


Move take off point after a block

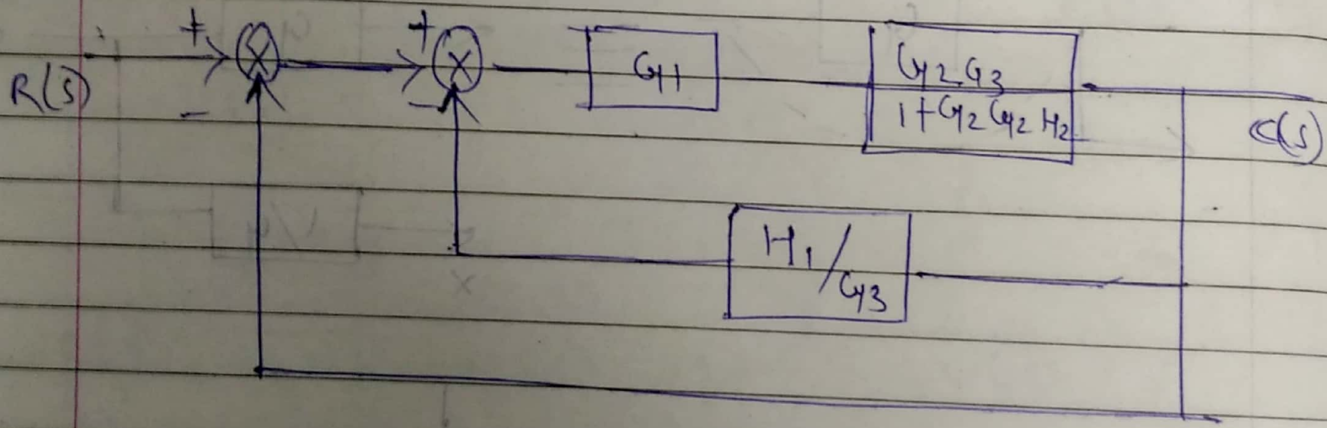




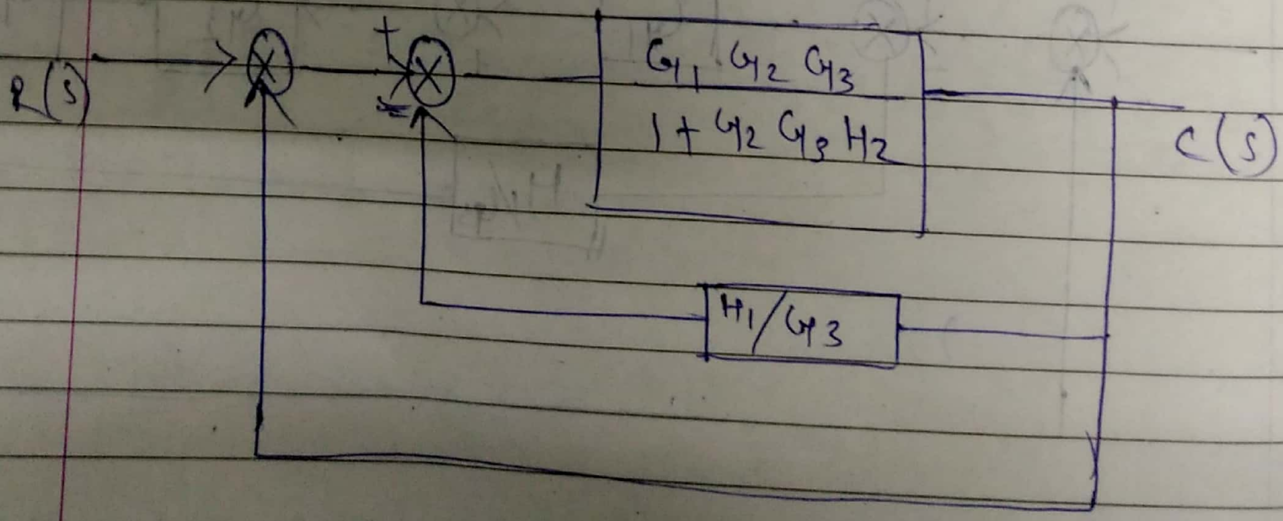
Apply rule No. 1



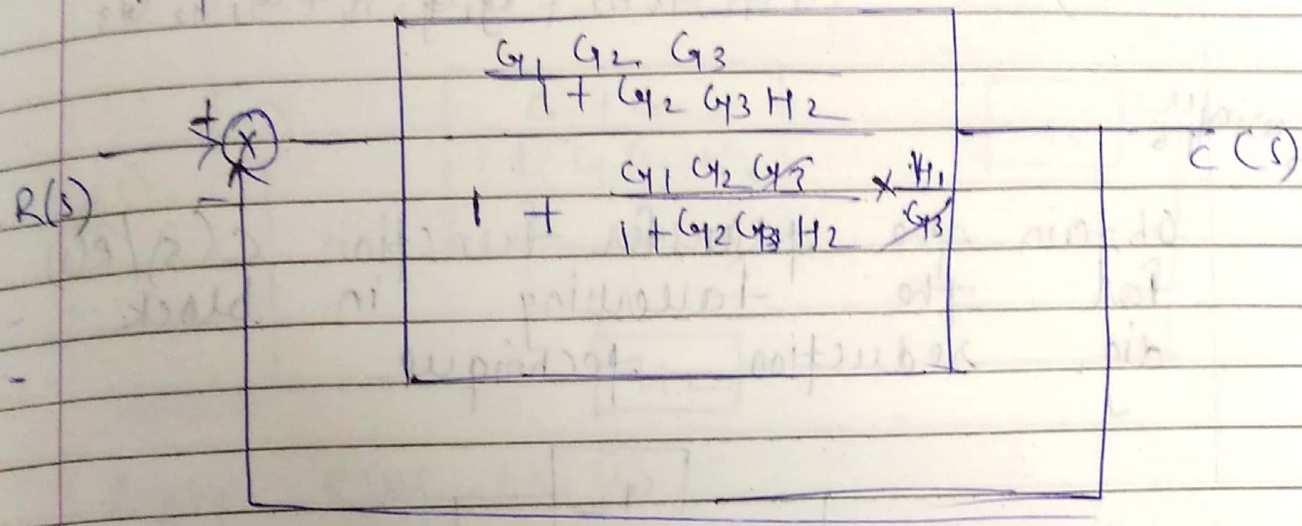
Apply rule no. 3.

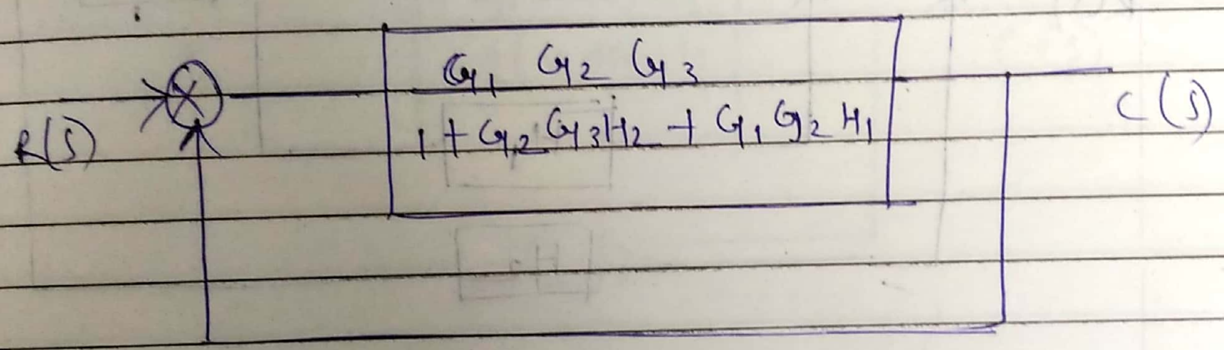


Apply rule no. 1.



Apply rule no. 3





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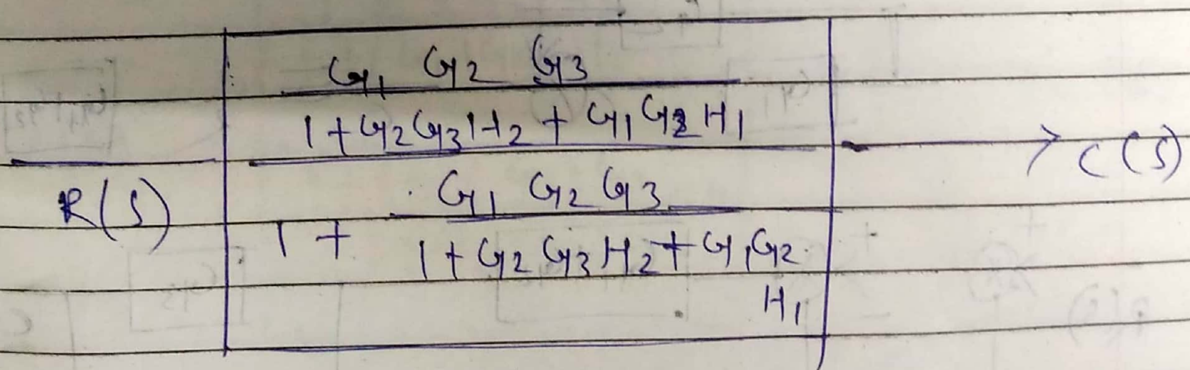
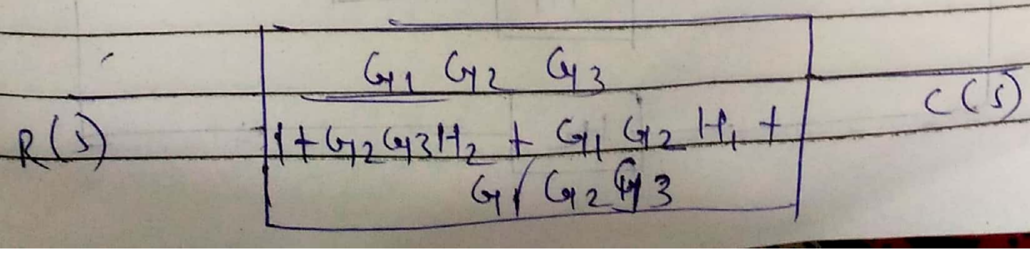
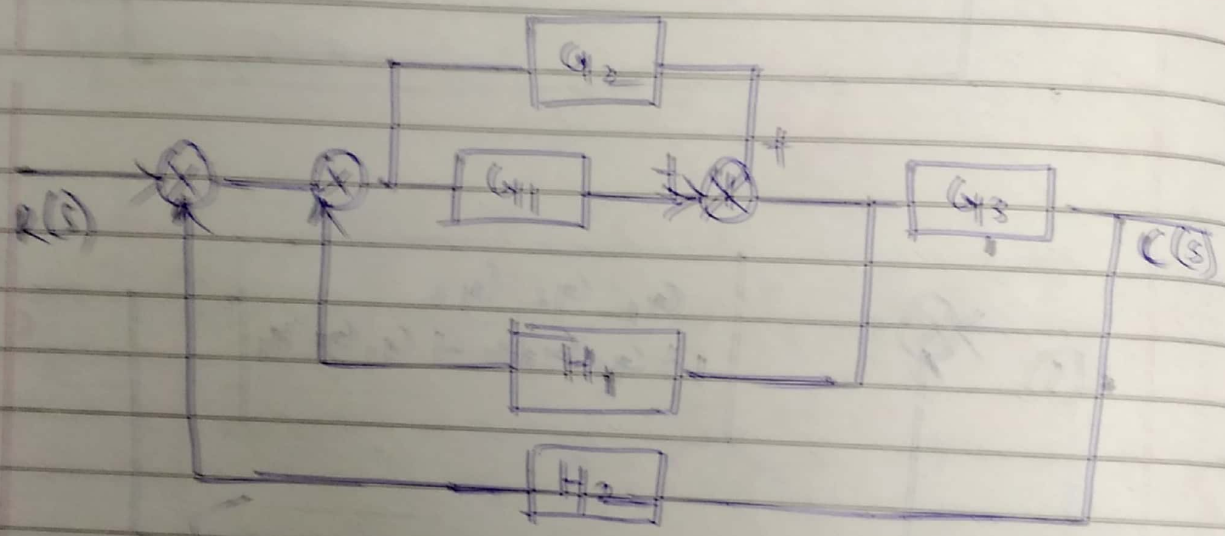




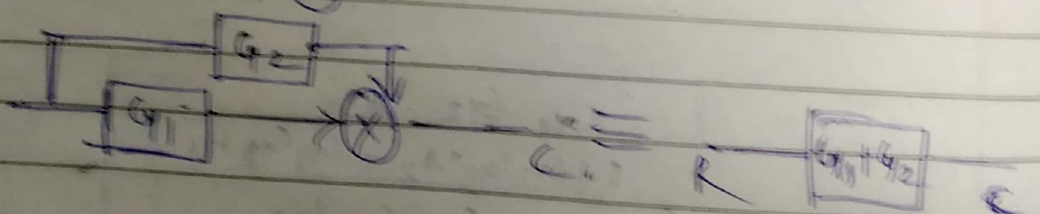
$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3}{1 + G_2 G_3 H_2 + G_1 G_2 H_1 + G_1 G_2 G_3}$$

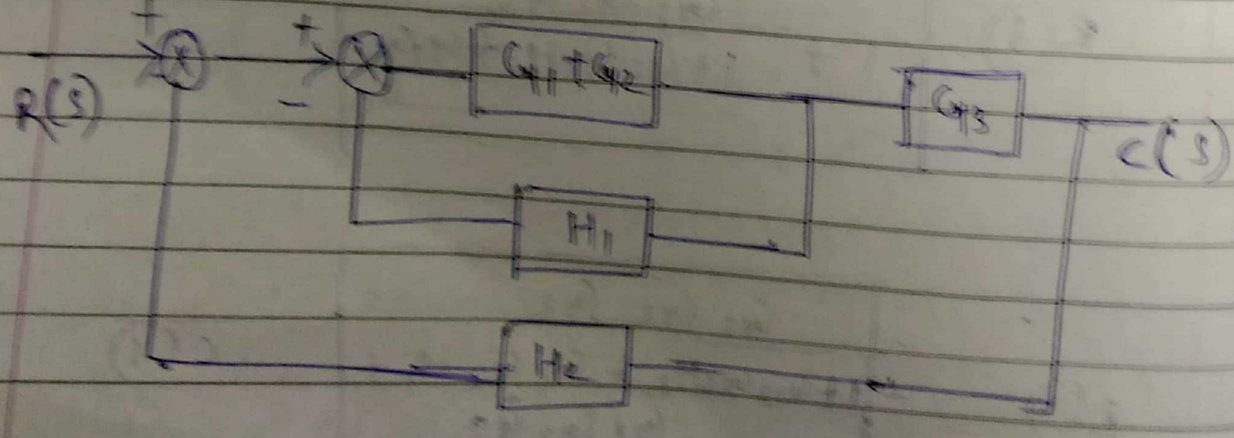
Q3 -

Obtain the transfer function $C(s)/R(s)$ for the following in block dig. reduction technique

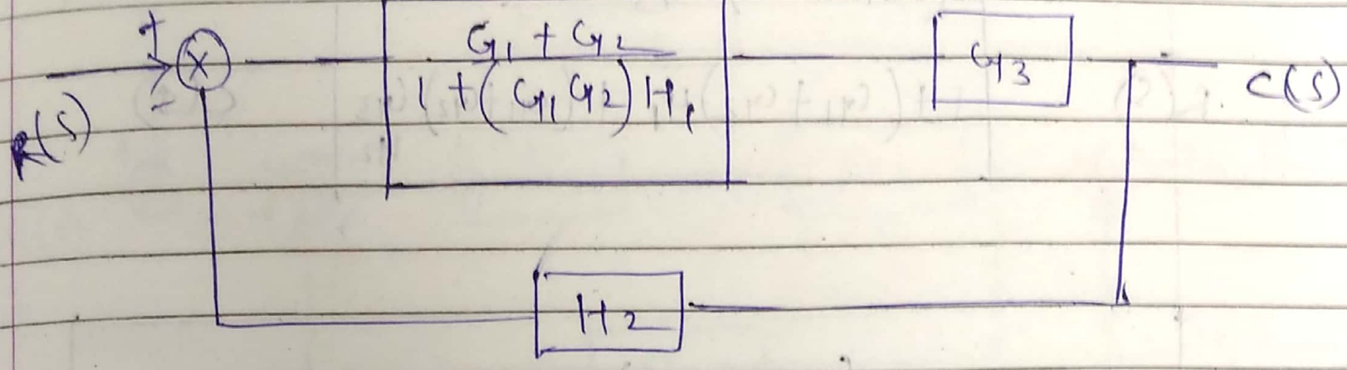


Apply rule no. 2

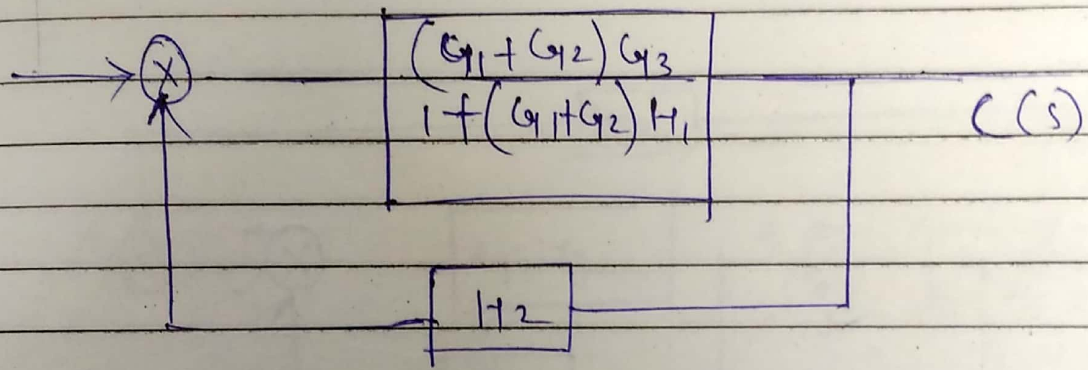


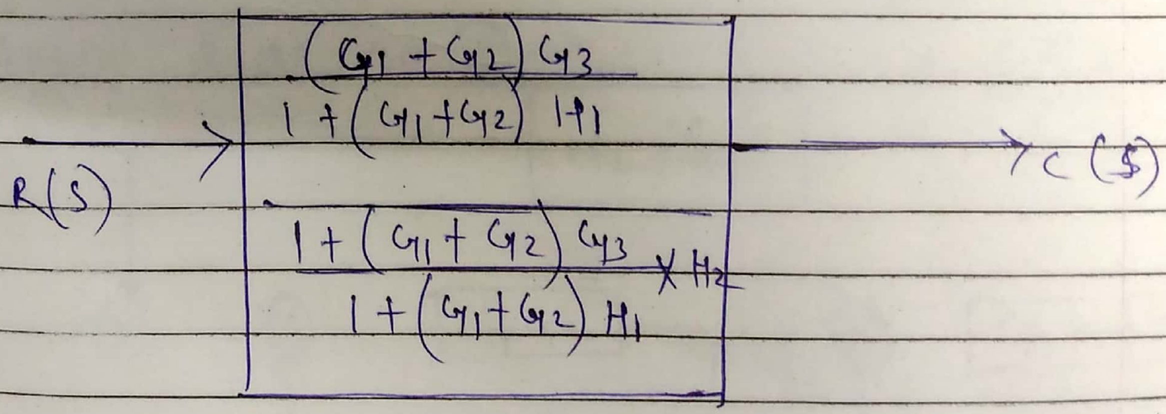


Apply Rule no. 3



Apply Rule no. 1



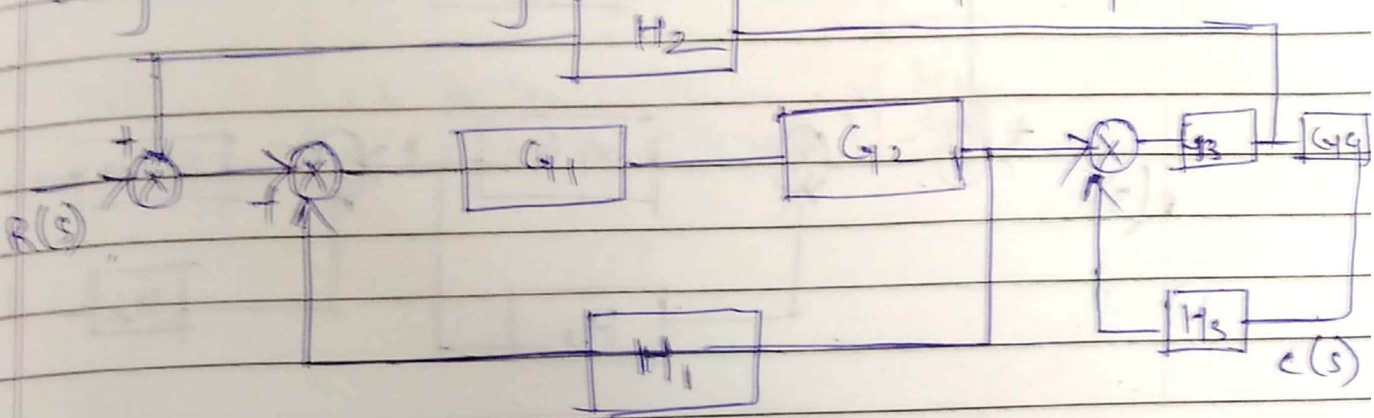


$$R(s) \rightarrow \boxed{\frac{(G_1+G_2)G_3}{1+(G_1+G_2)H_1+(G_1+G_2)G_3H_2}} \rightarrow C(s)$$

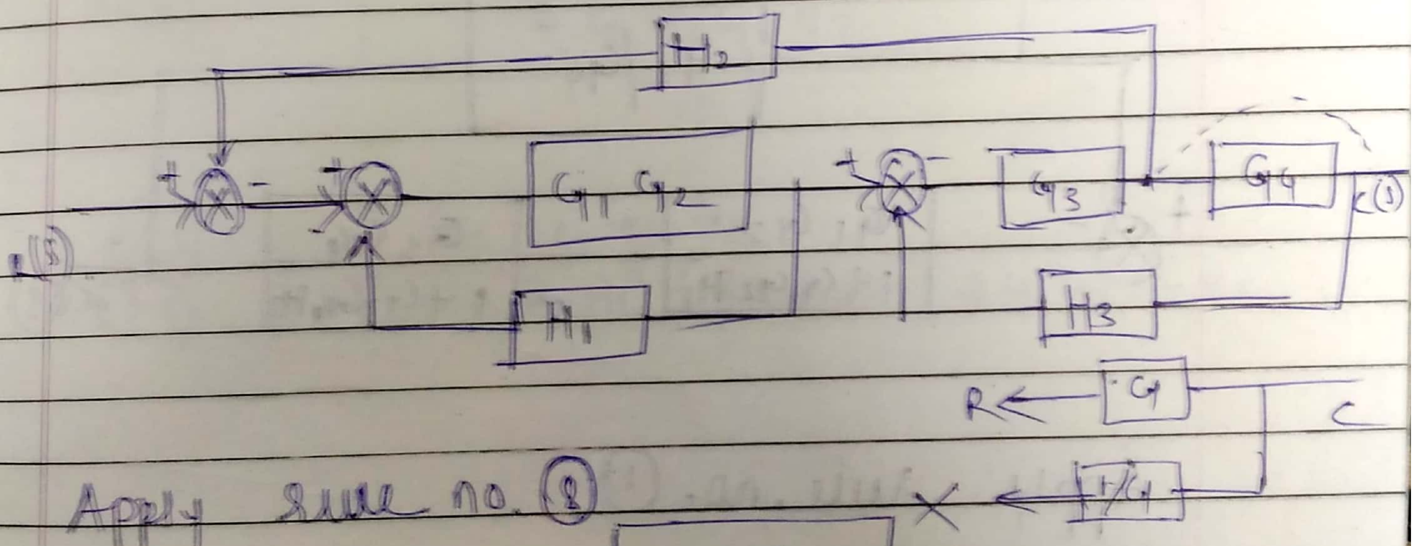
$$\boxed{\frac{C(s)}{R(s)} = \frac{(G_1+G_2)}{1+(G_1+G_2)H_1+(G_1+G_2)G_3H_2}}$$

serial = multiplication
parallel = addition

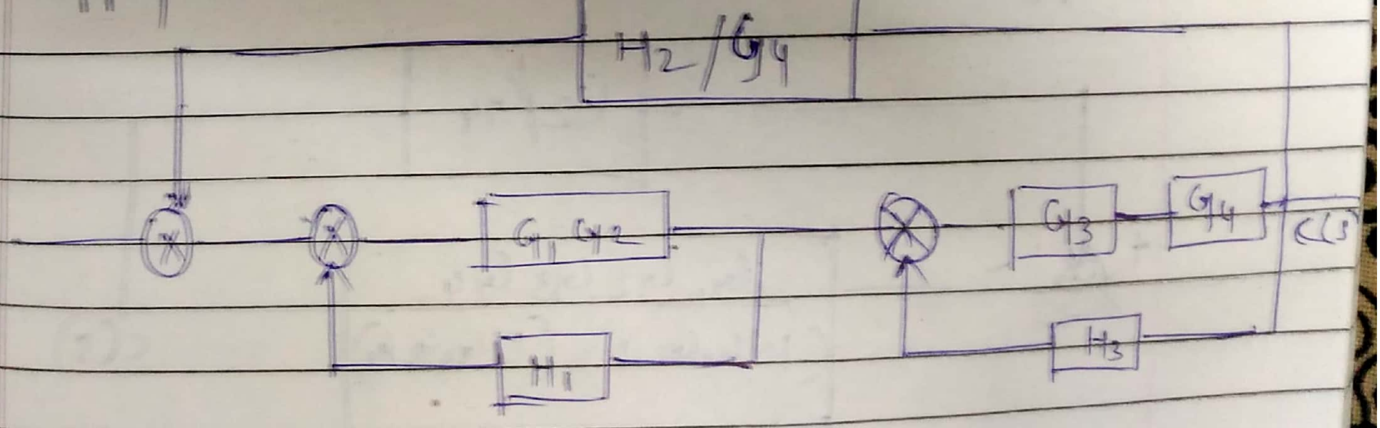
Q4- Determine the transfer function $\frac{C(s)}{R(s)}$ using block dig. reduction technique



Apply rule no. 1



Apply rule no. 8



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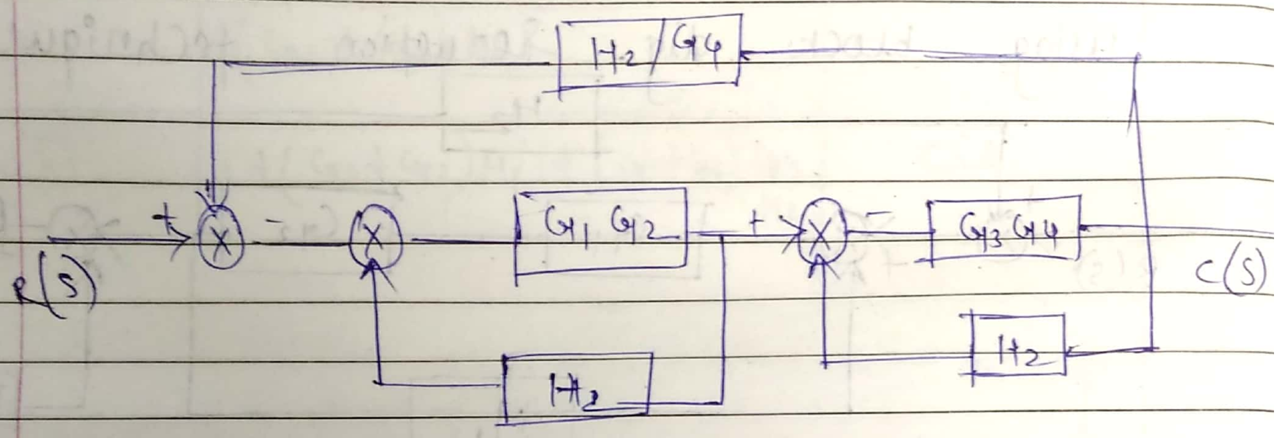
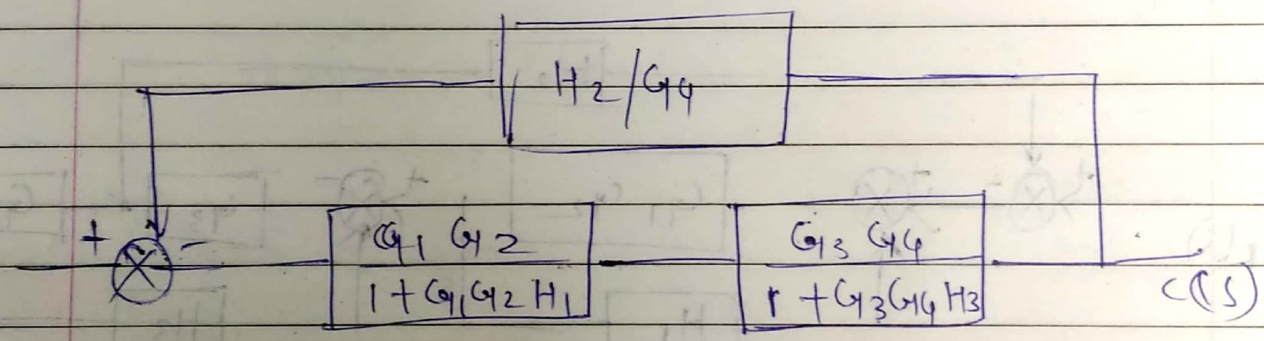
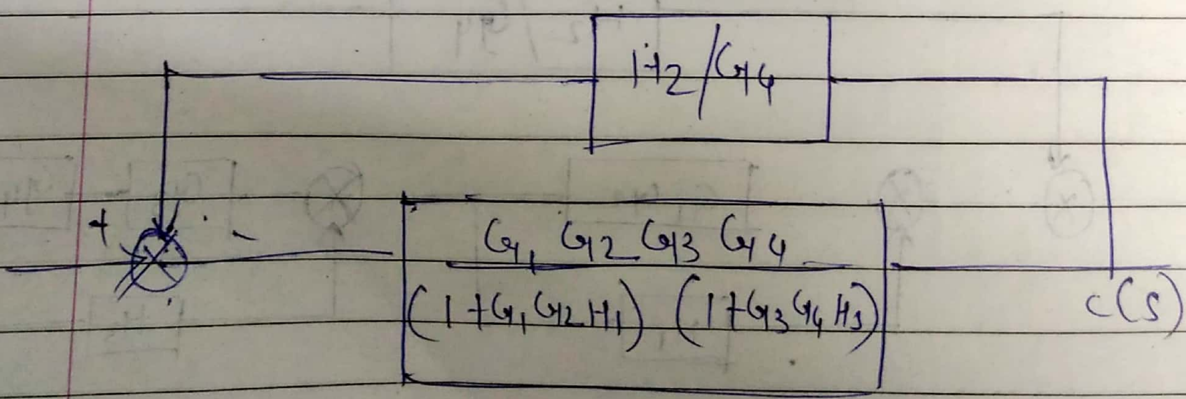
Apply Rule no. 1



Apply rule no. 3



Apply rule no. 1

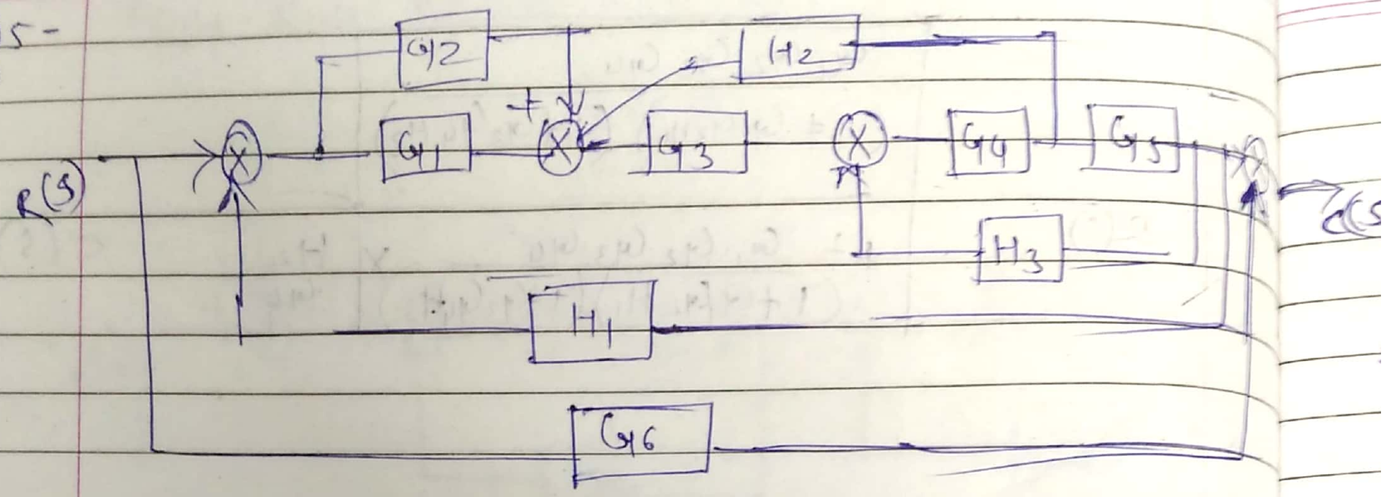


$$R(s) \longrightarrow \boxed{\dfrac{\dfrac{G_1 G_2 G_3 G_4}{(1+G_1 G_3 H_1)(1+G_3 G_4 H_3)}}{1+\dfrac{G_1 G_2 G_3 \cancel{G_4}}{(1+G_1 G_2 H_1)(1+G_3 G_4 H_3)} \times \dfrac{H_2}{\cancel{G_4}}}} \longrightarrow C(s)$$

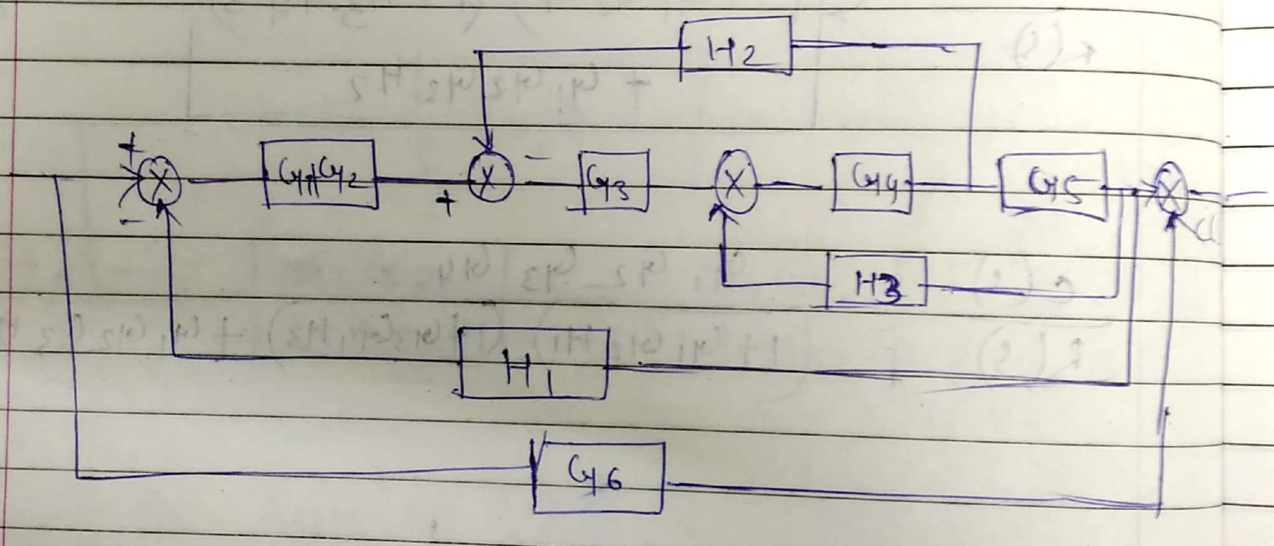
$$R(s) \longrightarrow \boxed{\dfrac{G_1 G_2 G_3 G_4}{(1+G_1 G_2 H_1)(1+G_3 G_4 H_3) + G_1 G_2 G_3 H_2}} \longrightarrow C(s)$$

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4}{(1+G_1 G_2 H_1)(1+G_3 G_4 H_3) + G_1 G_2 G_3 H_2}$$

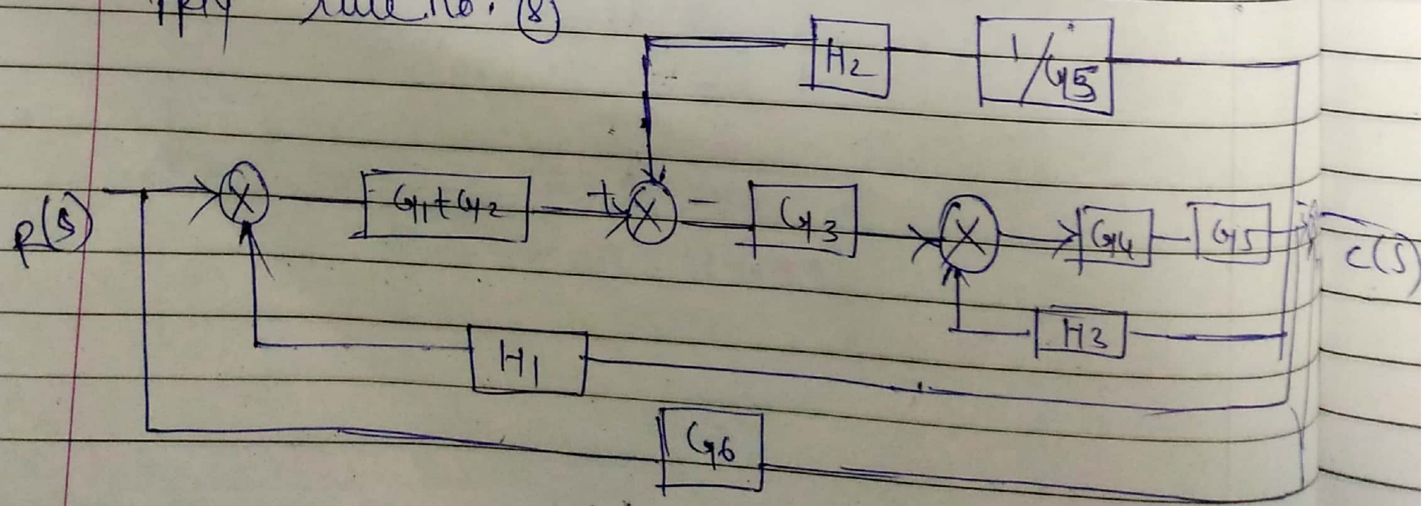
Q5 -



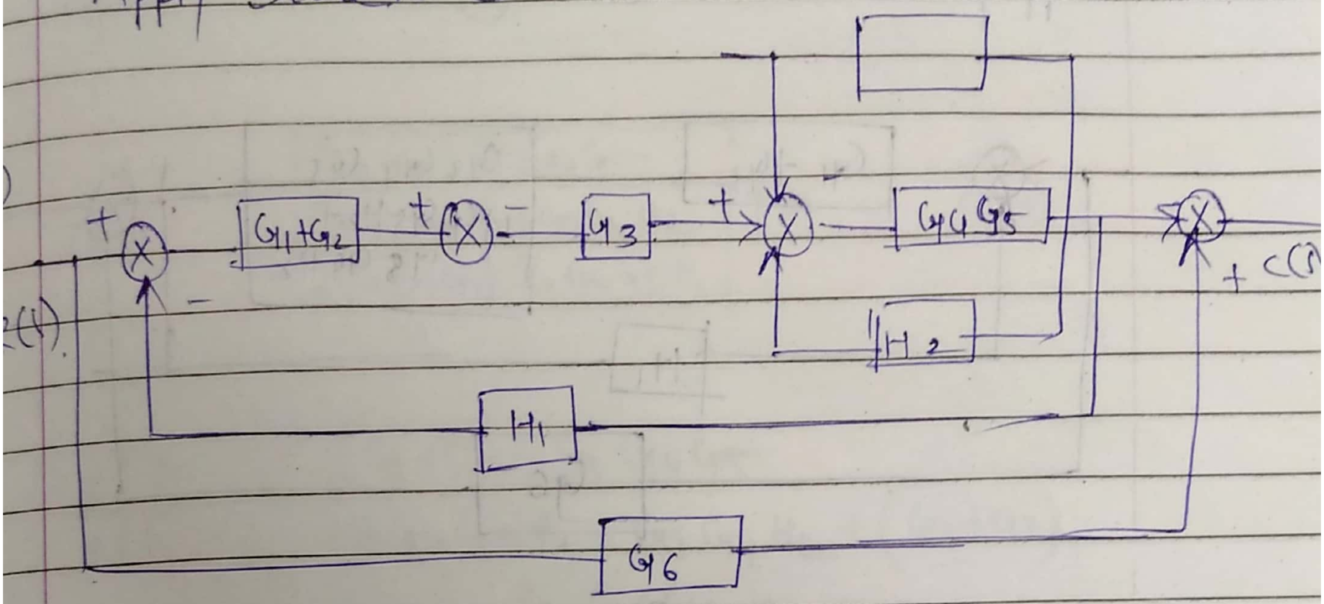
Soln: Apply Rule no. 2



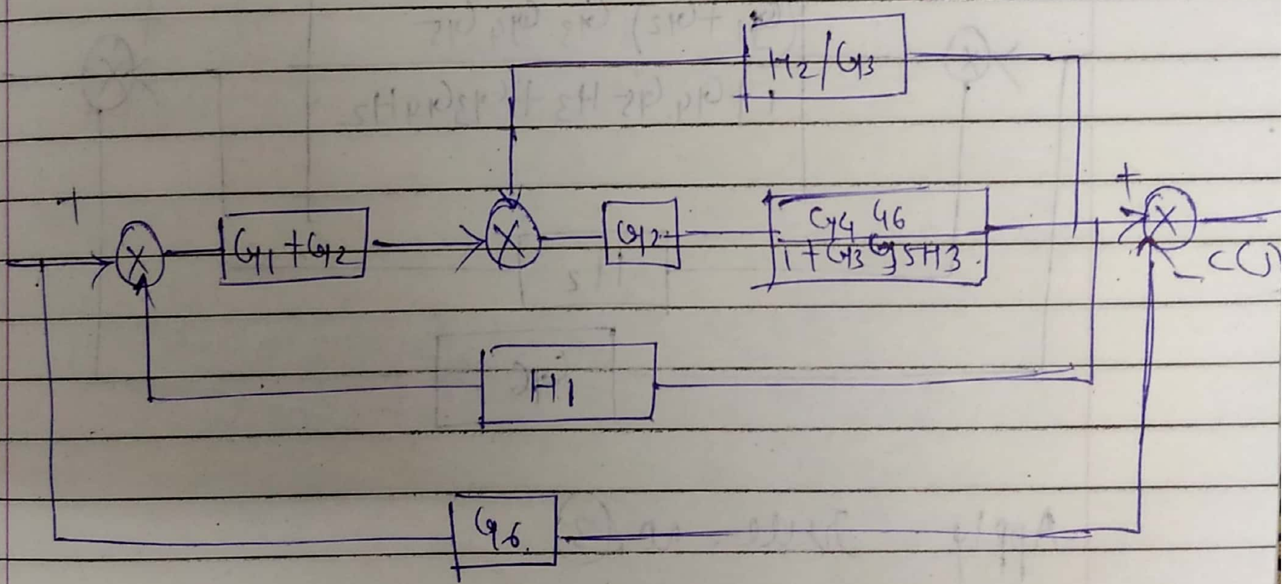
Apply Rule no. 8



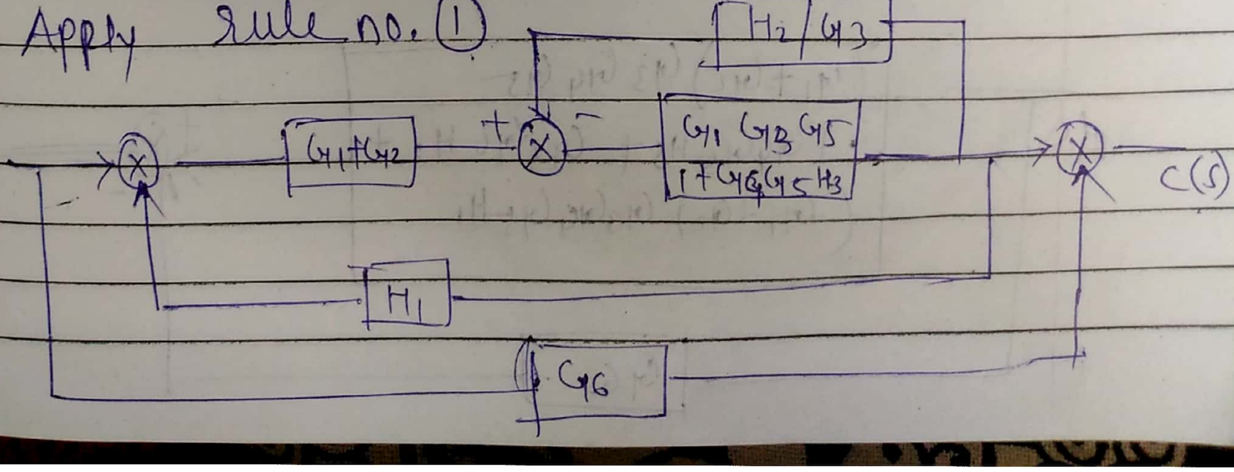
Apply rule no. 1



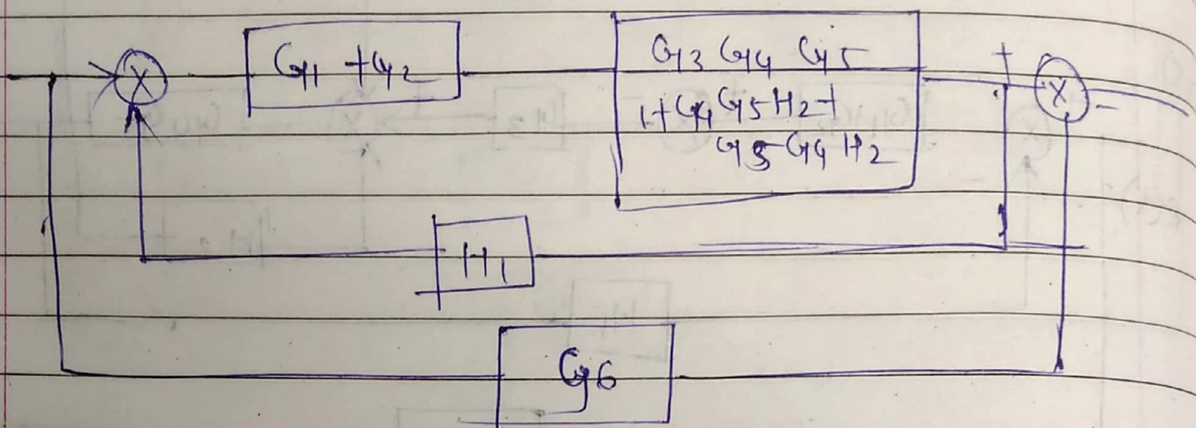
Apply rule no. 3



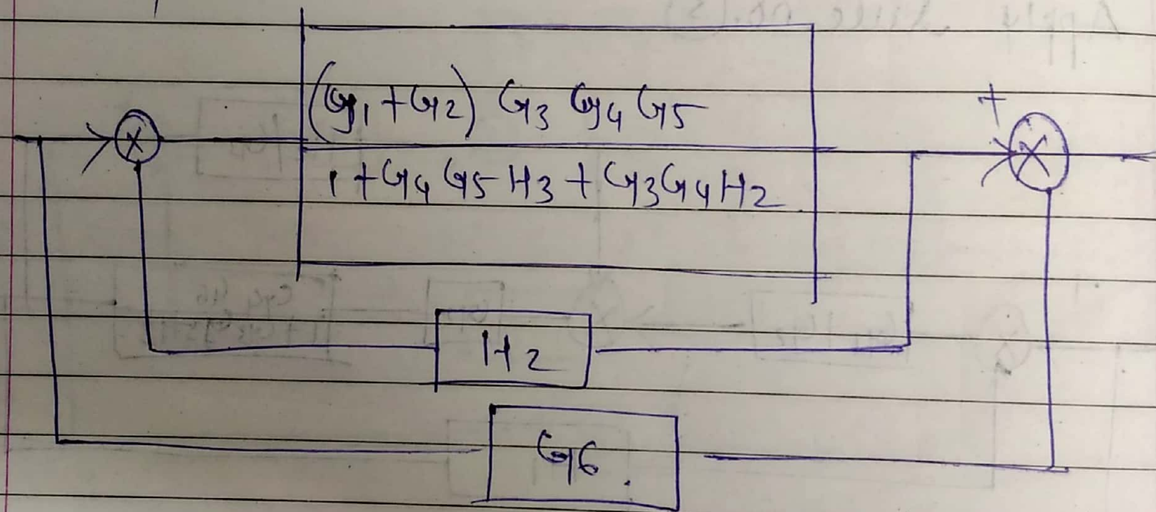
Apply rule no. 1



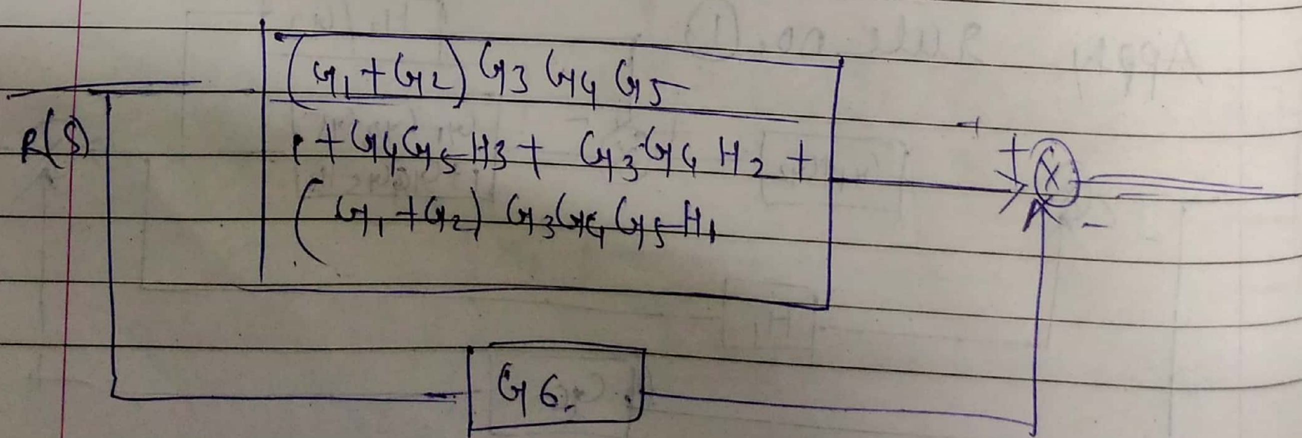
Apply rule no. 3



Apply rule no. 1



Apply rule no. 3

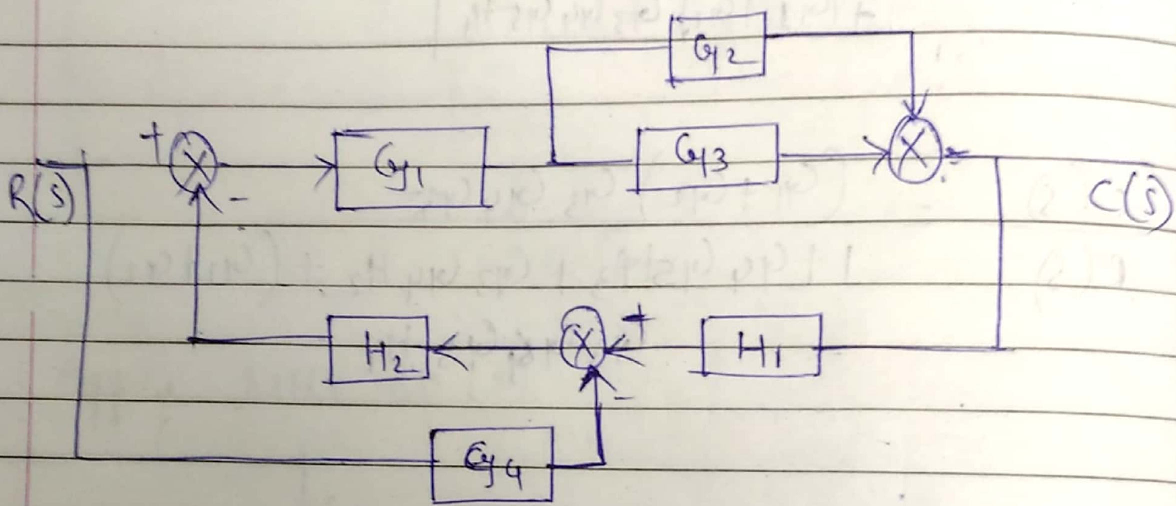


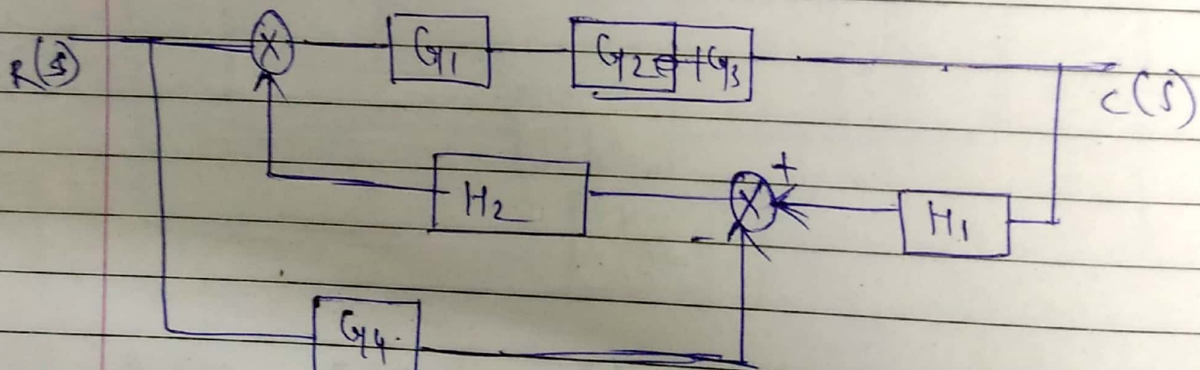
Apply rule no. 2

$$R(s) \longrightarrow \boxed{\frac{(G_1+G_2)\,G_3G_4G_5}{1+G_4G_5H_3+G_3G_4H_2+(G_1+G_2)\,G_3G_4G_5H_1}+G_6} \longrightarrow C(s)$$

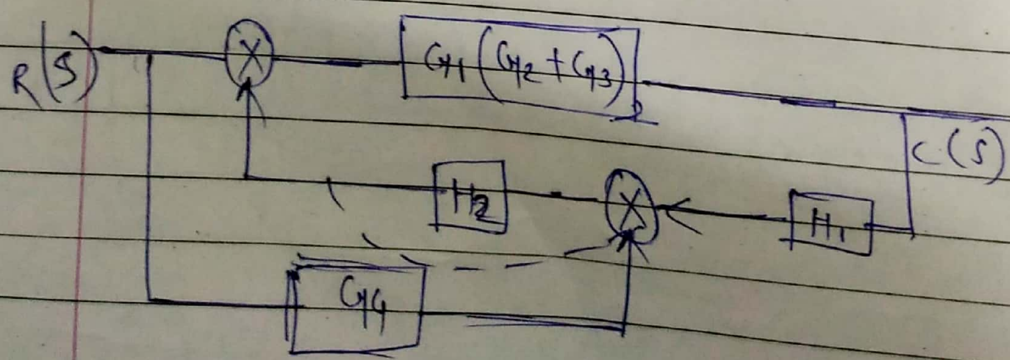
$$\frac{C(s)}{R(s)} = \frac{(G_1+G_2)\,G_3\,G_4\,G_5}{1+G_4G_5H_3+G_3G_4H_2+(G_1+G_2)\,G_3G_4G_5H_1}$$

Q6 - Reduce the following block dig. of the system shown in fig. and to find $\frac{C(s)}{R(s)}$

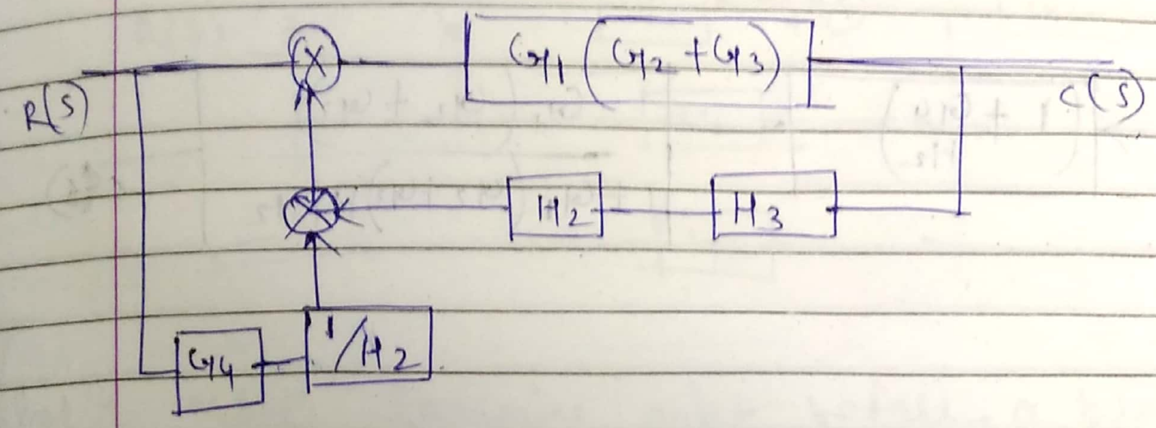


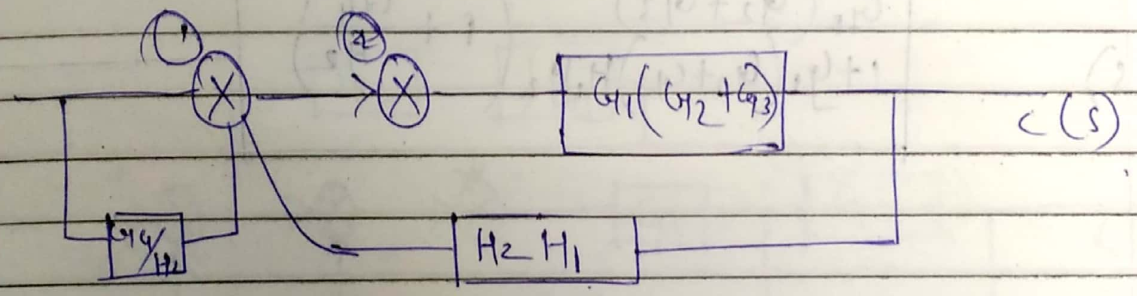


Apply rule no. 1

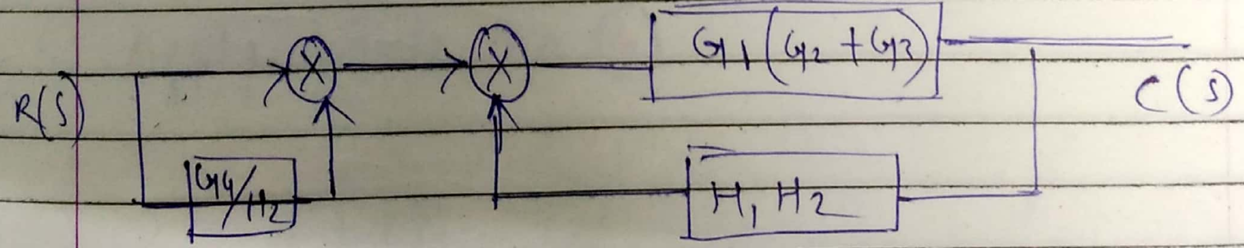


Apply rule no. 5

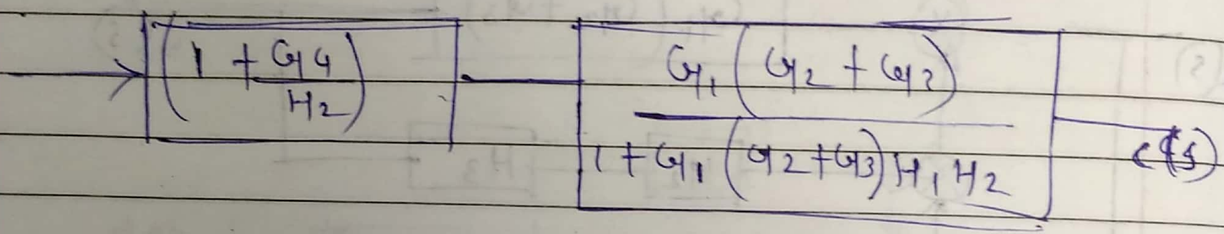


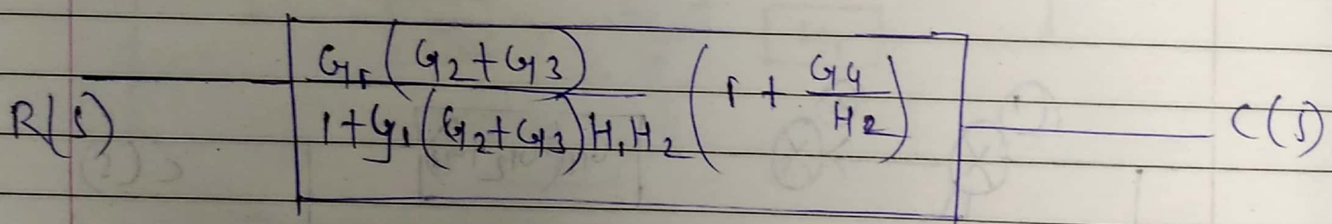


Apply rule no. 4

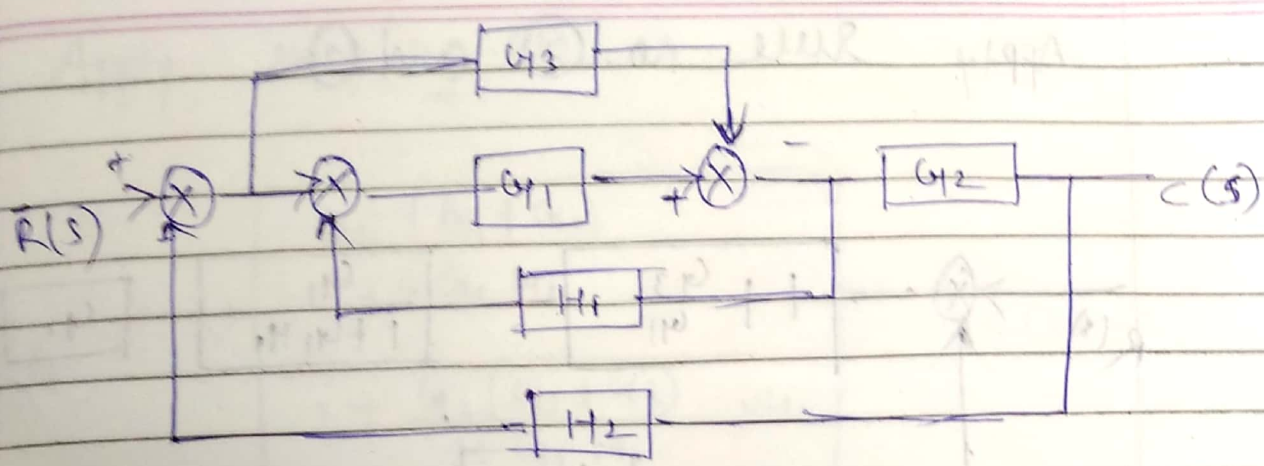


Apply rule (2) and (3)



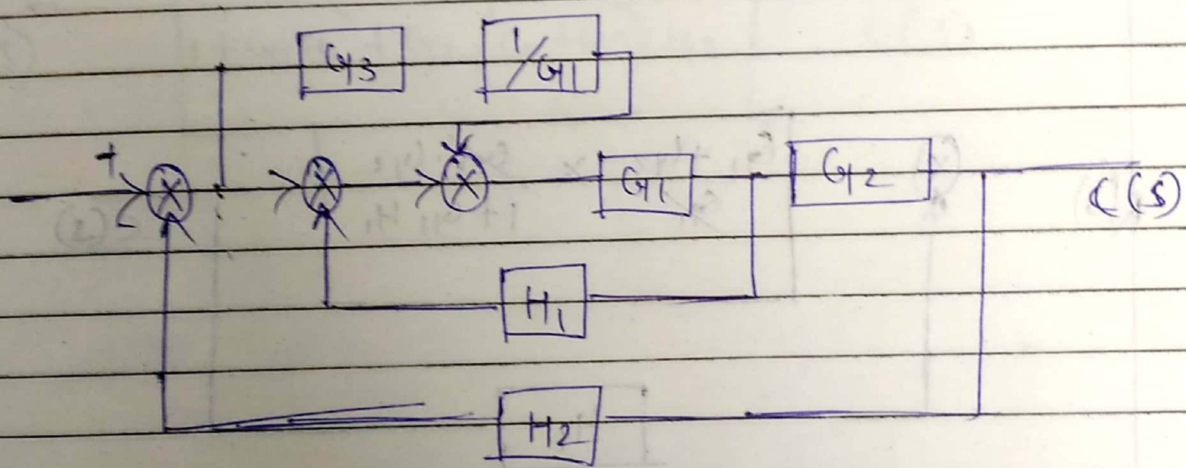


Q7-

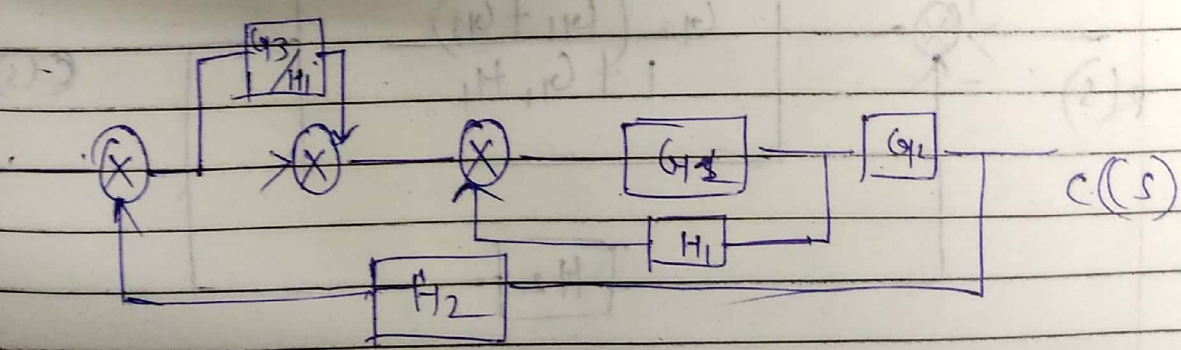


Sol^n:- move summing point before a block

Apply rule no. 5



Apply rule no. 4



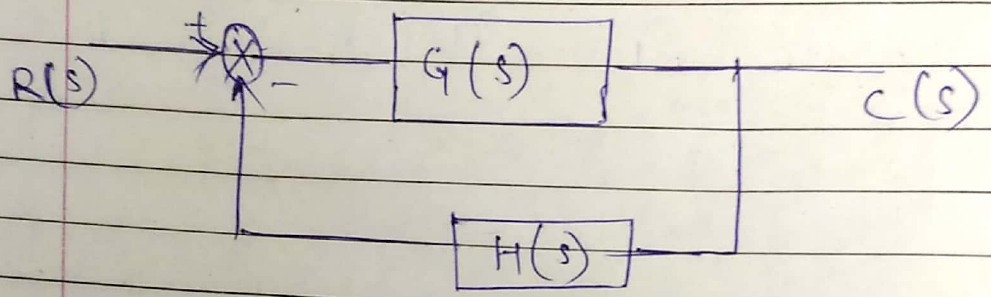
Apply rule no. 3

$$R(s) \longrightarrow \boxed{\dfrac{\dfrac{G_2(G_1+G_3)}{1+G_1H_1}}{1+\dfrac{G_2(G_1+G_3)}{1+G_1H_1}\times H_2}} \longrightarrow C(s)$$

$$R(s) \longrightarrow \boxed{\dfrac{G_2(G_1+G_3)}{1+G_1H_1+G_2(G_1+G_3)H_2}} \longrightarrow C(s)$$

Transfer Function

* Derivation of transfer function



Let, $r(t)$ = input signal
$c(t)$ = controlled o/p signal
$E(t)$ = error signal
$b(t)$ = F/b o/p signal
$R(s)$ = L.T of $r(t)$
$c(s)$ = L.T. of $c(t)$
$e(B)$ = L.T. of $f(t)$
$b(s)$ = L.T. of $b(t)$

The open loop gain is defined as

$$G(s) = \frac{C(s)}{E(s)}$$

The F/b g is defined as

$$H(s) = \frac{B(s)}{C(s)} = B(s) = C(s).H(s)$$

error signal is given by

$$E(s) = R(s) \pm B(s)$$
$$E(s) = R(s) \pm C(s) \cdot H(s)$$
$$R(s) = E(s) \pm R(s) \cdot H(s)$$

The T.F. is defined as the ratio of L.T. of output response to the L.T. of input response.

$$T.F. = \frac{C(s)}{R(s)}$$

$$= \frac{C(s)}{E(s) \pm C(s) \cdot H(s)}$$

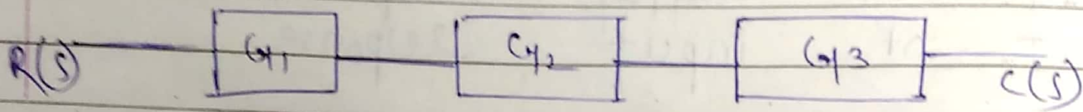
divide: by numerator and denominator E(s

$$= \frac{C(s) / E(s)}{1 \pm \frac{C(s)}{E(s)} \times H(s)}$$

$$\boxed{T.F. = \frac{G(s)}{1 \pm G(s) \cdot H(s)}}$$

Rules of Block Reduction Technique

Rule No: 1) Two or more number of blocks are connected in series or Cascad



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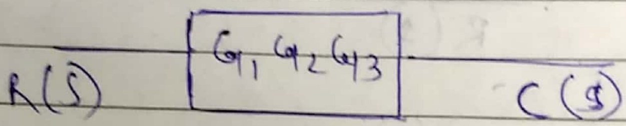
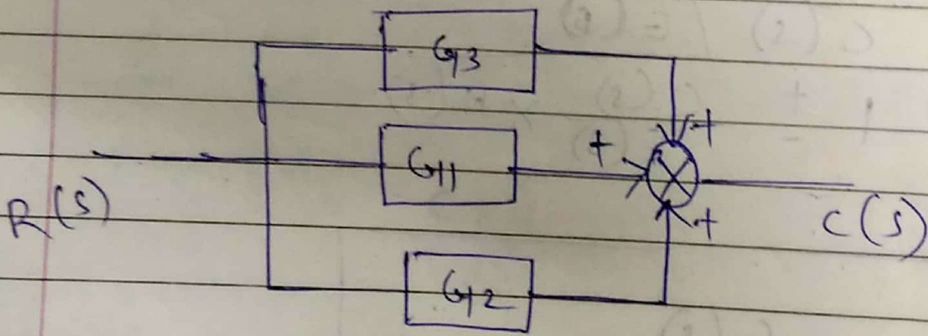


Rule No:- 2) Two or more number of blocks are connected in parallel



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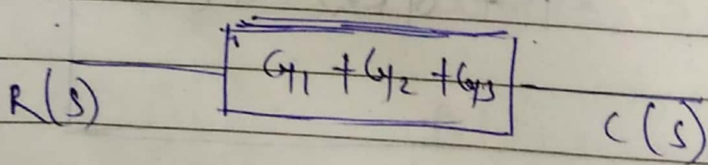

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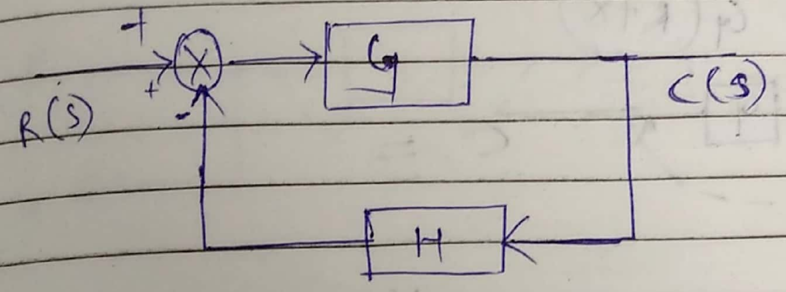
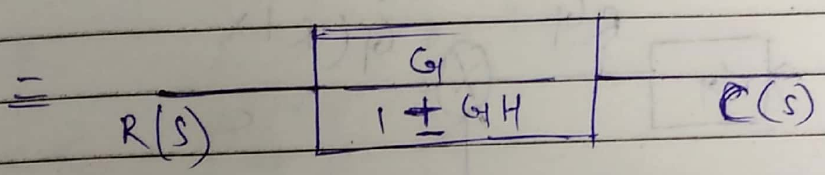
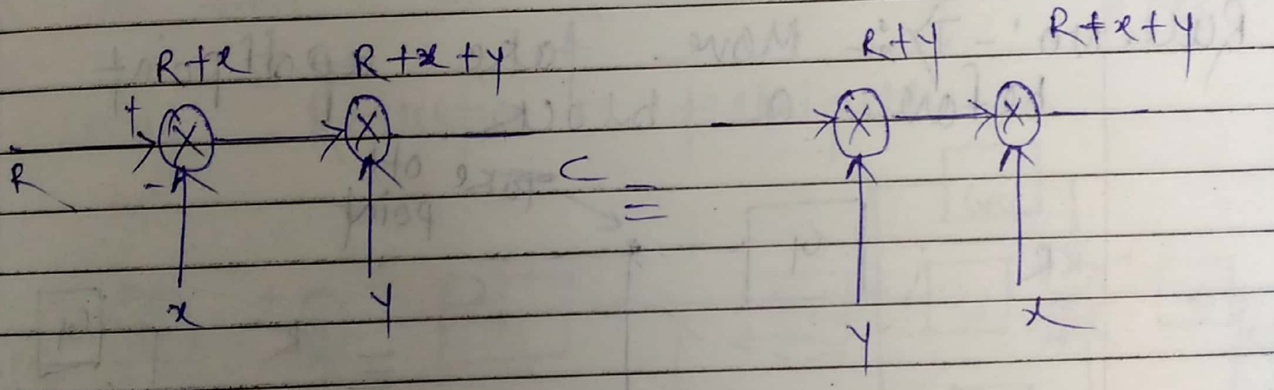
Rule No:3) Complete loop

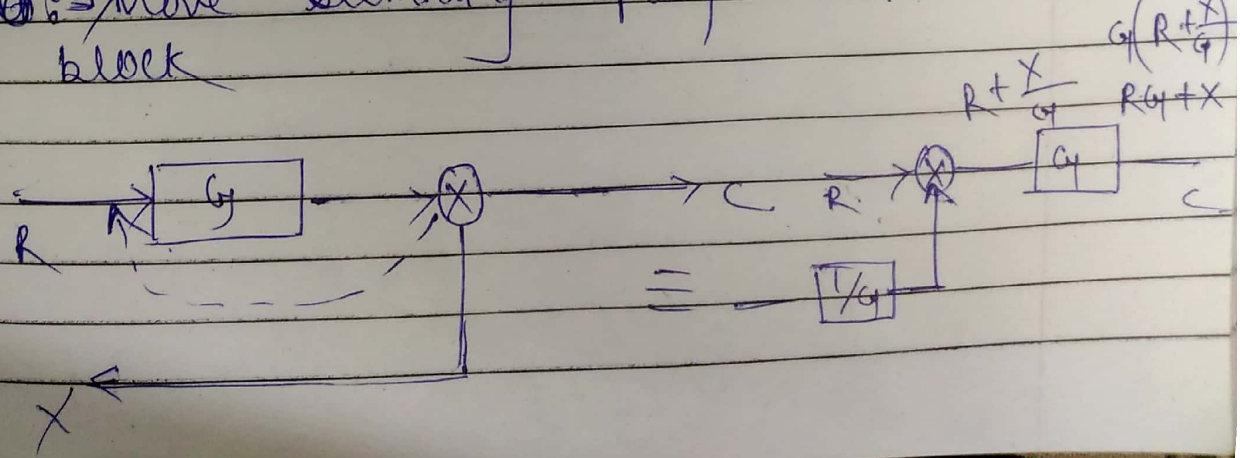




Rule No:-4) Associative property



Rule No:5) Move summing point before a block



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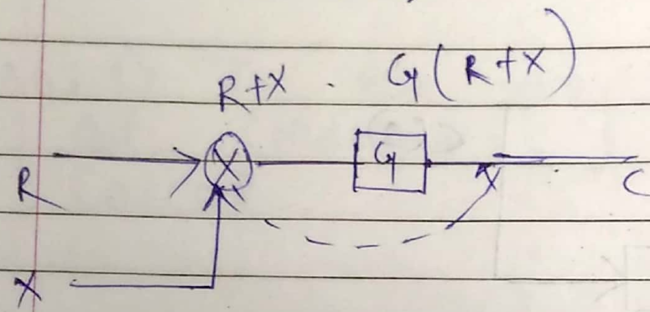
Rule No:-6) Move summing point after a block.



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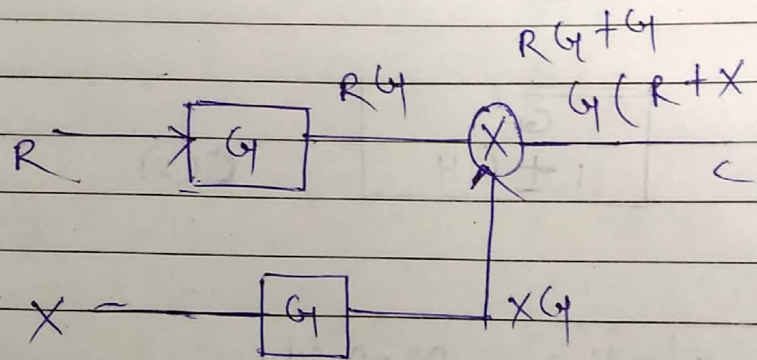
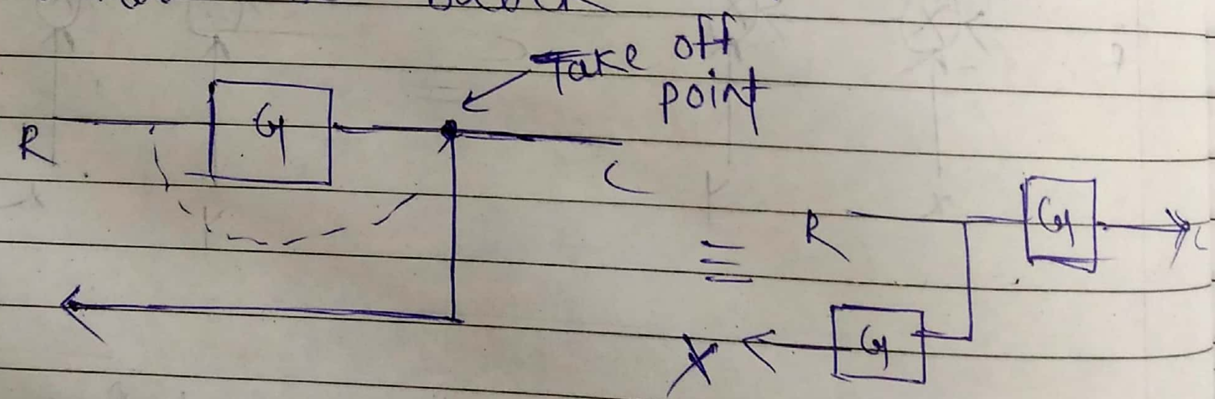
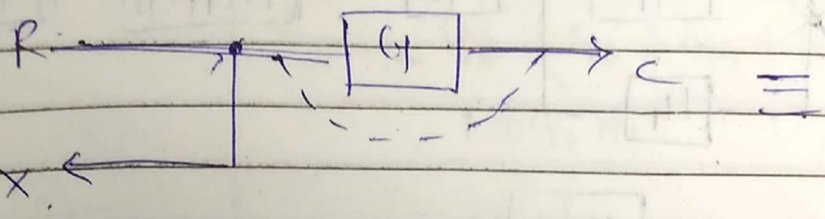
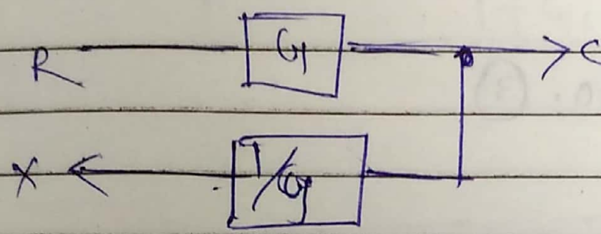


Rule No:-7) :- Move take ~~up~~ off point before a block



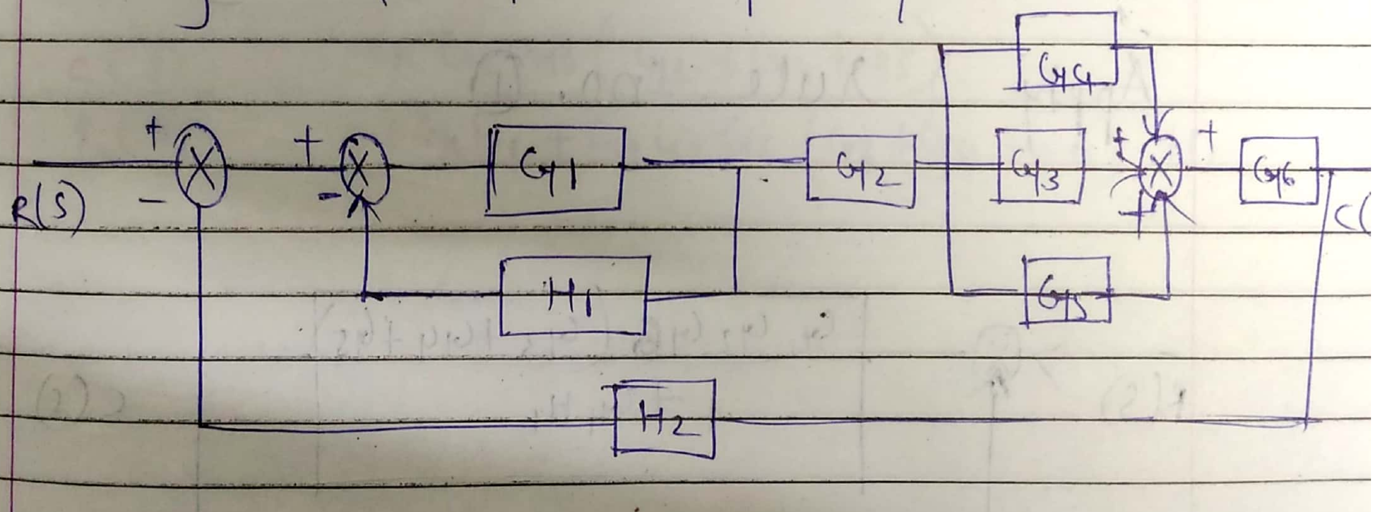
Rule No:- 8) Move take off point after a block





Example:-

1) To find the transfer function $\frac{C(s)}{R(s)}$ using Reduction techniques



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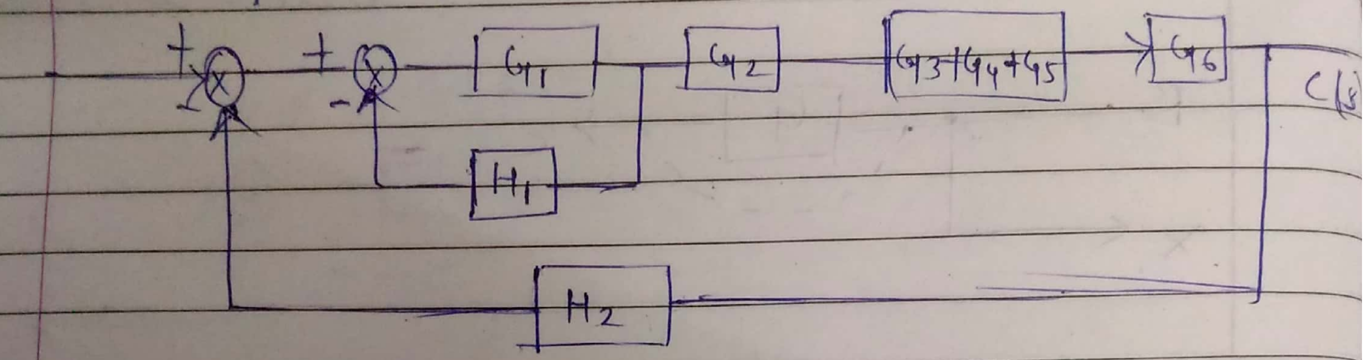
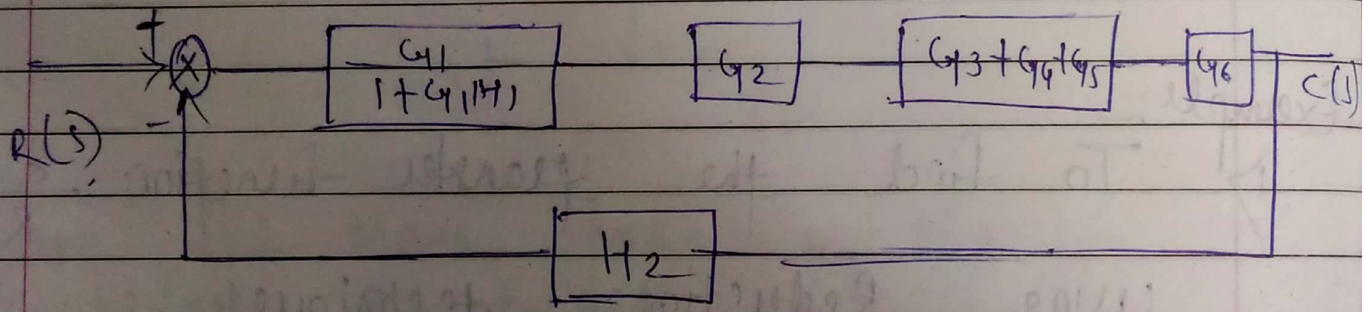
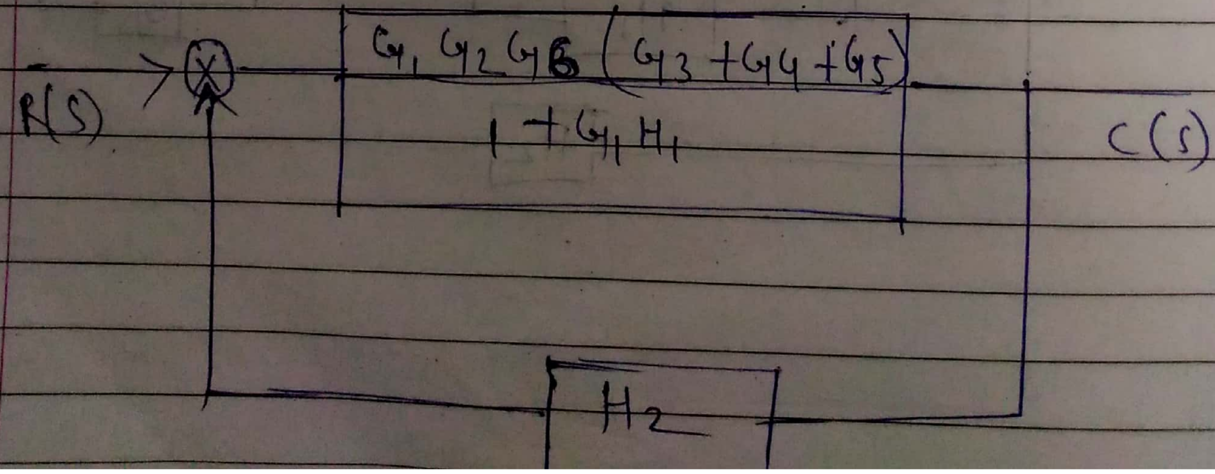
Sol^n:- Apply rule no. 2



Apply rule no. 3



Apply rule no. 1



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Apply rule no. 3

$$R(s) \longrightarrow \boxed{\dfrac{\dfrac{G_1 G_2 G_6 (G_3 + G_4 + G_5)}{1 + G_1 H_1}}{1 + \dfrac{G_1 G_2 G_6 (G_3 + G_4 + G_5)}{1 + G_1 H_1} \times H_2}} \longrightarrow C(s)$$

$$R(s) \longrightarrow \boxed{\dfrac{G_1 G_2 G_6 (G_3 + G_4 + G_5)}{1 + G_1 H_1 + G_1 G_2 G_6 (G_3 + G_4 + G_5) H_2}} \longrightarrow C(s)$$

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_6 (G_3 + G_4 + G_5)}{1 + G_1 H_1 + G_1 G_2 G_6 (G_3 + G_4 + G_5) . H_2}$$

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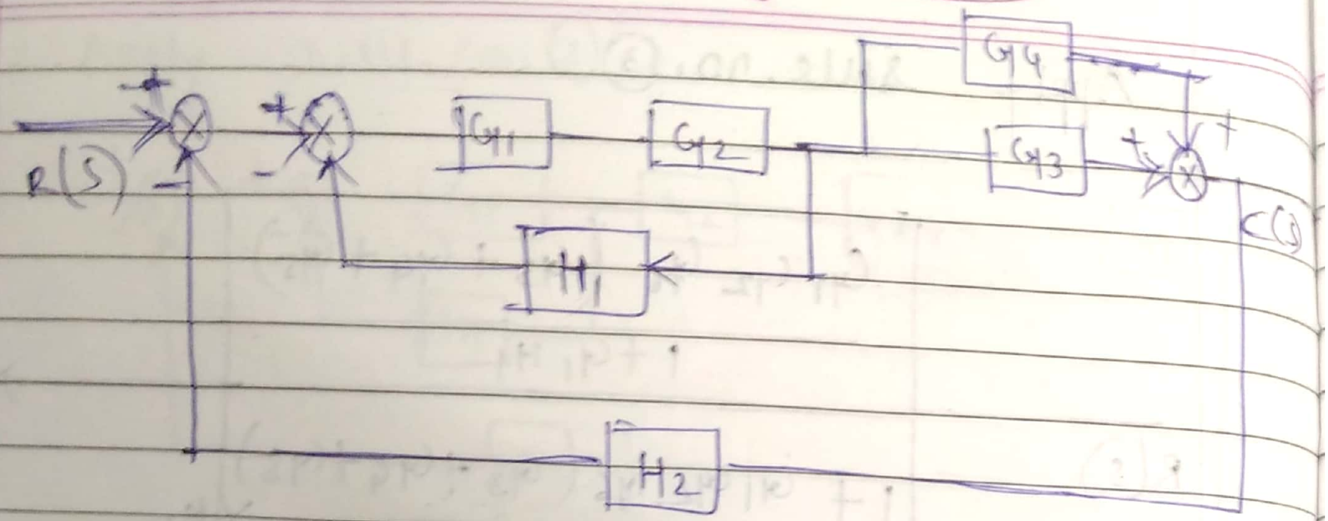
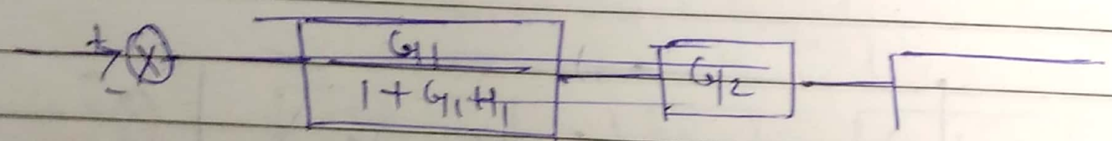
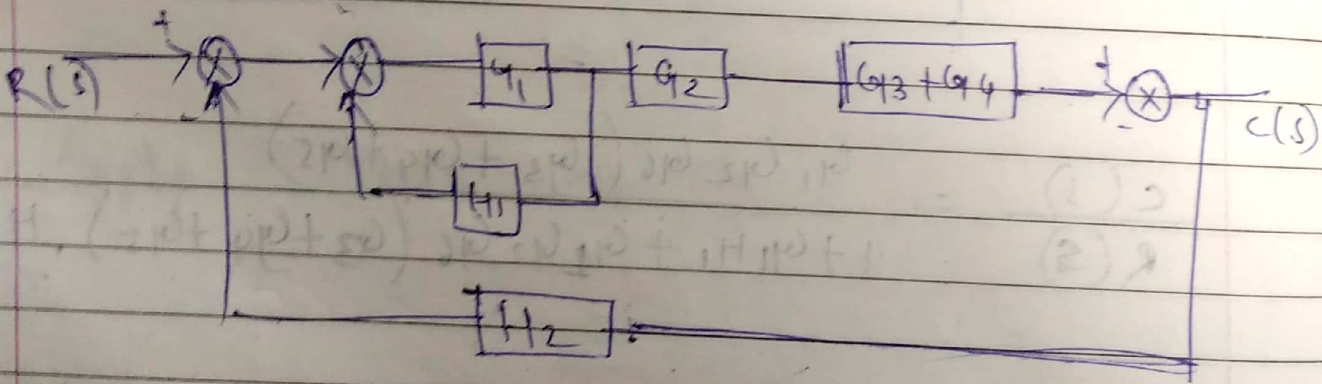


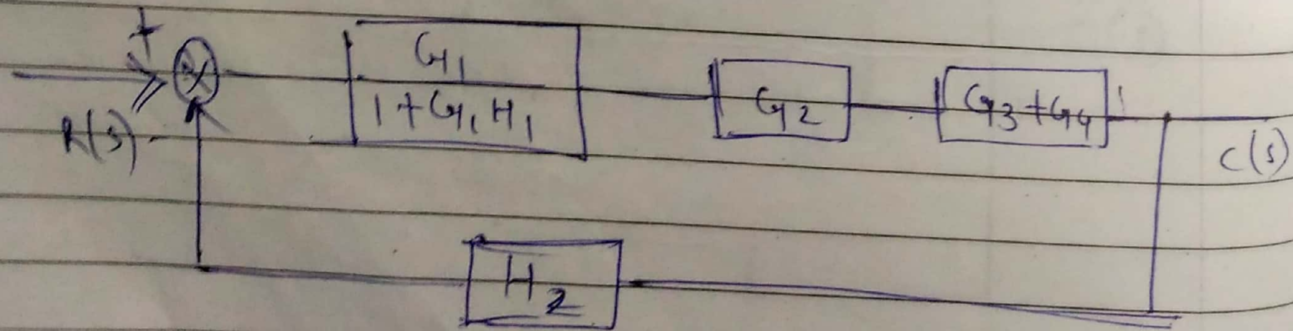
ln:- Apply rule no. 3



Apply rule no. 2



Apply rule no. 3



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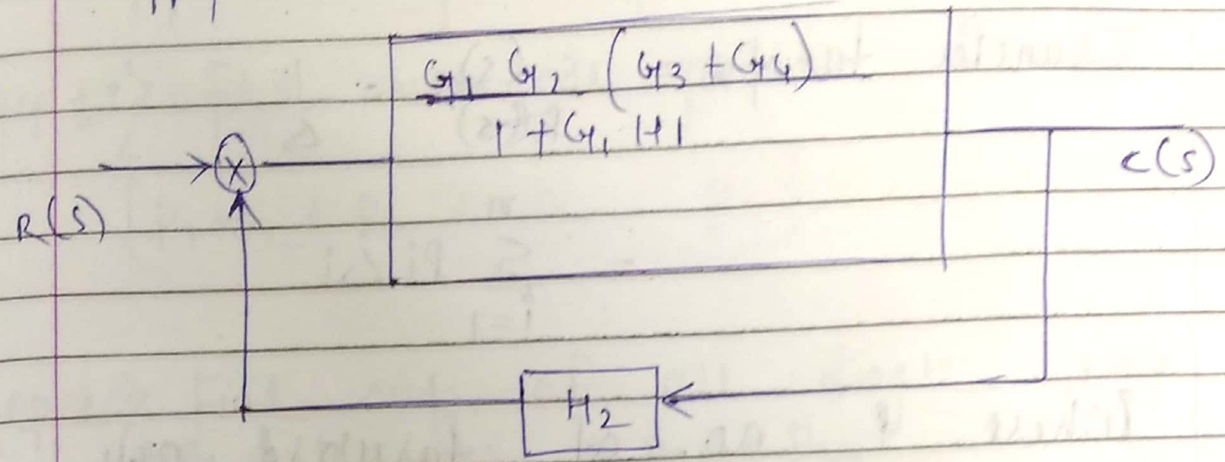
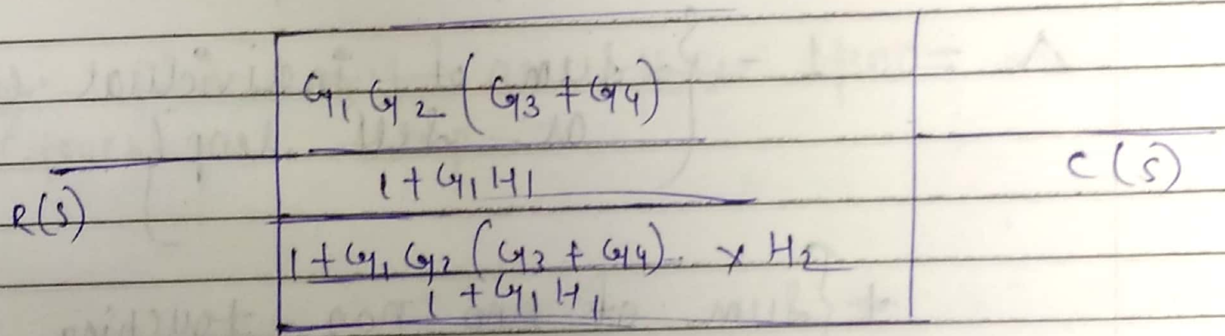
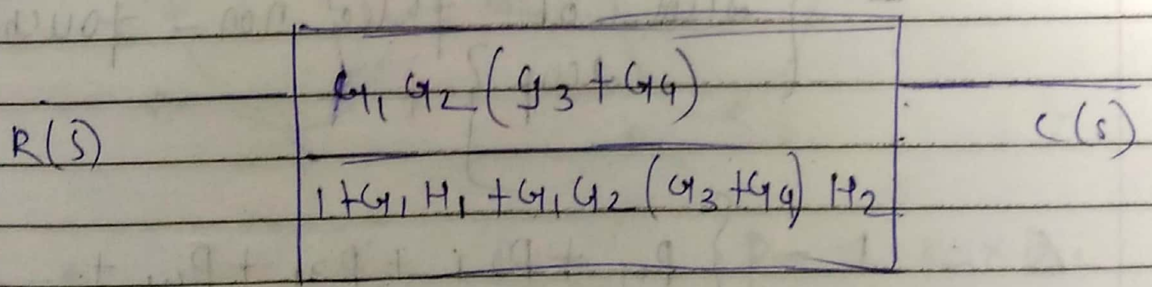
Apply rule no. 1



Apply rule no. 3





$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 (G_3 + G_4)}{1 + G_1 H_1 + G_1 G_2 (G_3 + G_4) H_2}$$

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Signal flow Graph (SFG)

Transfer function $= \frac{C(s)}{R(s)} = \frac{1}{\Delta}$

$$= \sum_{i=1}^{n} P_i \Delta_i$$

where i no. of forward path

P_i = Gain of forward path

Δ = System determinant.

$\Delta = 1 - \{$ sum of individual loop or self loop $\}$

$+ \{$ sum of two non-touching loop $\}$

$- \{$ sum of three non-touching loop $\} + \text{---}$

$$\Delta = 1 - \{P_{11} + P_{21} + P_{31} + P_{41} + \text{---} P_{n1}\}$$

$$+ \{\cancel{P_{21}} + P_{22} + P_{32} + P_{42} + \text{---} + P_{n2}\}$$

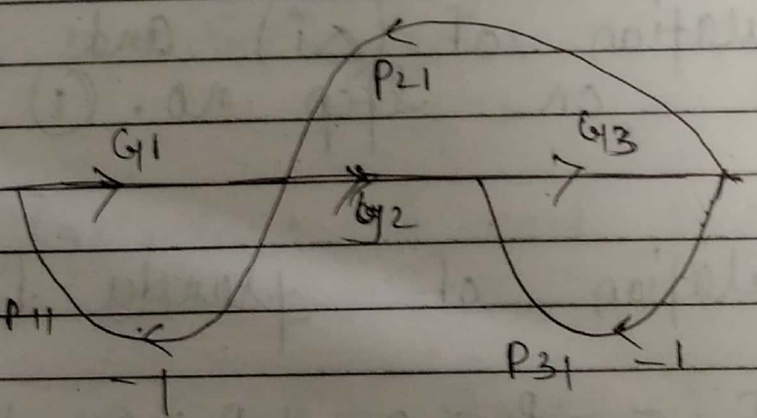
$$- \{P_{13} + P_{23} + P_{33} + \text{---} + P_{n3}\} + \text{---}$$

Step Solving using mason's formula

Step 1:> Find out all posible forward path
[$P_1 + P_2 + P_3 + \text{---} P_n$]

Step 2:> Find out of all single loop in SFG i.e. [~~$P_{12} + P_{22} + P_{33}$~~]
[$P_{11} + P_{21} + P_{31} + P_{41} + \text{---} P_{n1}$]

Step 3:- Find out all ~~three~~ two non-touching loop



~~P12~~ P_{12}, P_{22}, P_{32} $\quad P_{12} = P_{11} \times P_{31}$

Step 4:- Find out all three non-touching loop.

Step 5:- Calculation of d(Δ) delta.

$$\Delta = 1 - \{P_{11} + P_{21} + P_{31} + P_{41} + \cdots + P_{n1}\}$$
$$+ \{P_{12} + P_{22} + P_{32} + \cdots + P_{n2}\}$$
$$- \{P_{13} + P_{23} + P_{33} + \cdots + P_{n3}\} +$$
$$+ \cdots$$

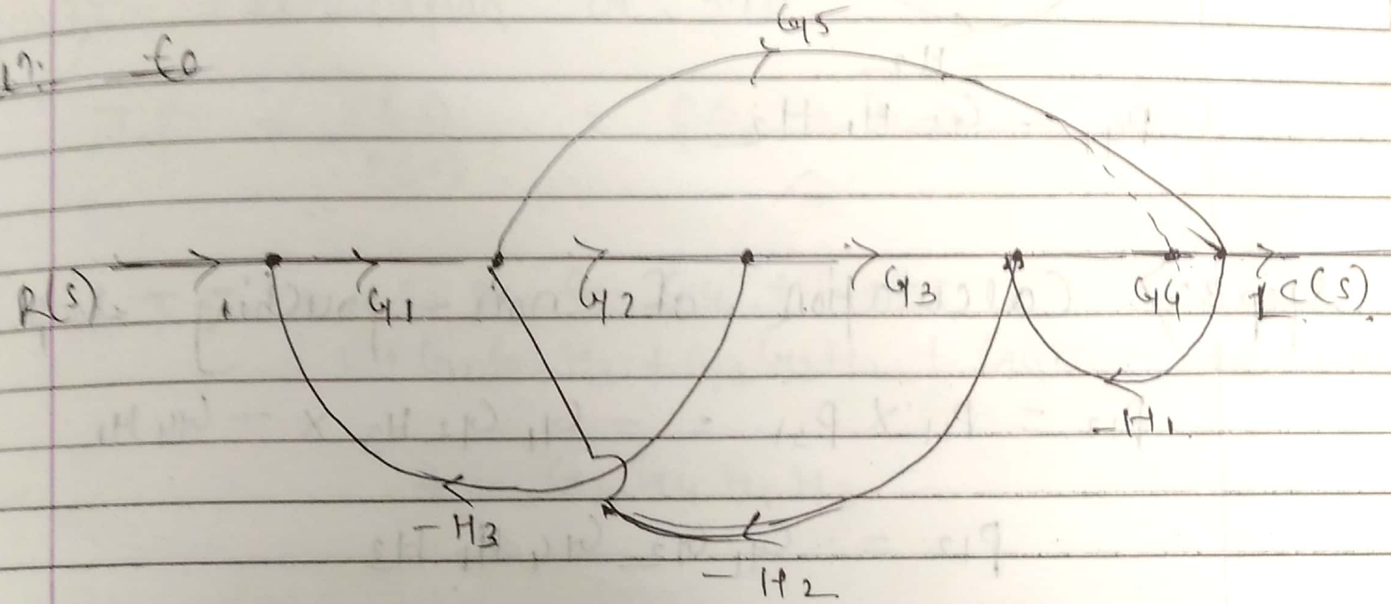
Step 6:- Calculation of (Δi) and Δi depends on step no. 1

Step 7:- Calculation of transfer function T.F.

$$T.F. = \frac{P_1 \times \Delta_1 + P_2 \times \Delta_2 + P_3 \times \Delta_3 + \cdots + P_n \times \Delta_n}{\Delta}$$

Q- Find the transfer function $\frac{C(s)}{R(s)}$ from signal flow graph.

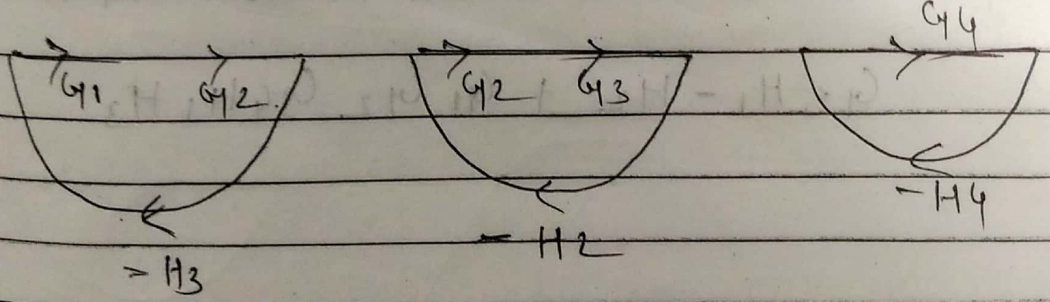
Sol^n:



Step 1:- calculation of forward path

~~P11~~ $P_1 = G_1 G_2 G_3 G_4$ $\qquad$ $P_2 = G_1 G_5$

Step 2 :- Calculation of self loop



$P_{11} = -G_1 G_2 H_3$ $\qquad$ $P_{21} = -G_2 G_3 H_2$ $\qquad$ $P_{31} = -G_4 H_1$

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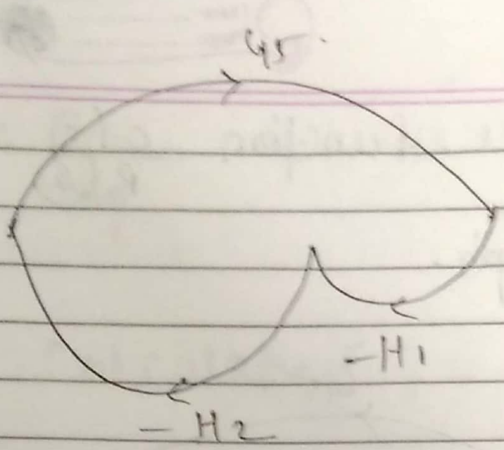


$P_{41} = G_5 H_1 H_2$

Step 3:-> Calculation of non-touching loop

$P_{12} = P_{11} \times P_{31} = -G_1 G_2 H_3 \times -G_4 H_1$

$P_{12} = G_1 G_2 G_4 H_1 H_3$

Step 5):-> Calculation of Δ

$$\Delta = 1 - [P_{11} + P_{21} + P_{31} + P_{41}] + P_{12}$$

$$\Delta = 1 + G_1 G_2 H_3 + G_2 G_3 H_2 + G_4 H_1 - G_5 H_1 - H_2 + G_1 G_2 G_4 H_1 H_3$$

Step 6:- Calculation of Δi

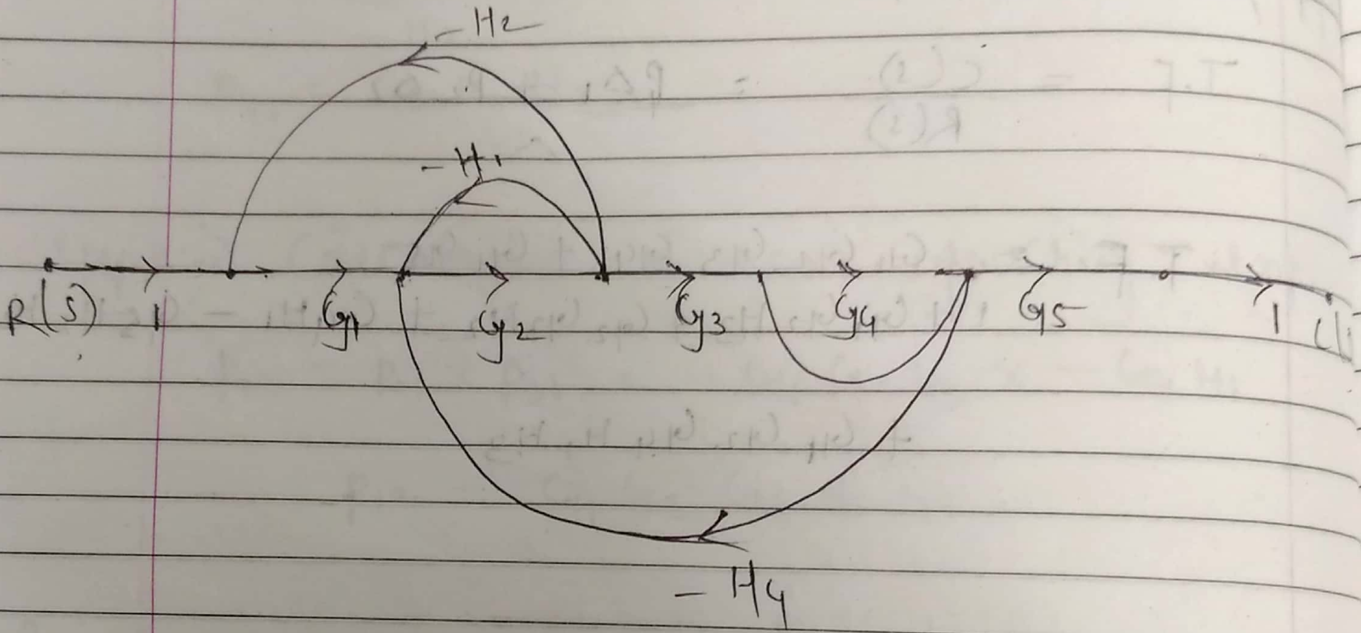
$\Delta_1 = \Delta_2 = 1$

Step 7:- Calculation of T.F.

$$T.F. = \frac{C(s)}{R(s)} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$$T.F. = \frac{G_1 G_2 G_3 G_4 + G_1 G_5}{1 + G_1 G_2 H_3 + G_2 G_3 H_2 + G_4 H_1 - G_5 H_1 H_2 + G_1 G_2 G_4 H_1 H_3}$$

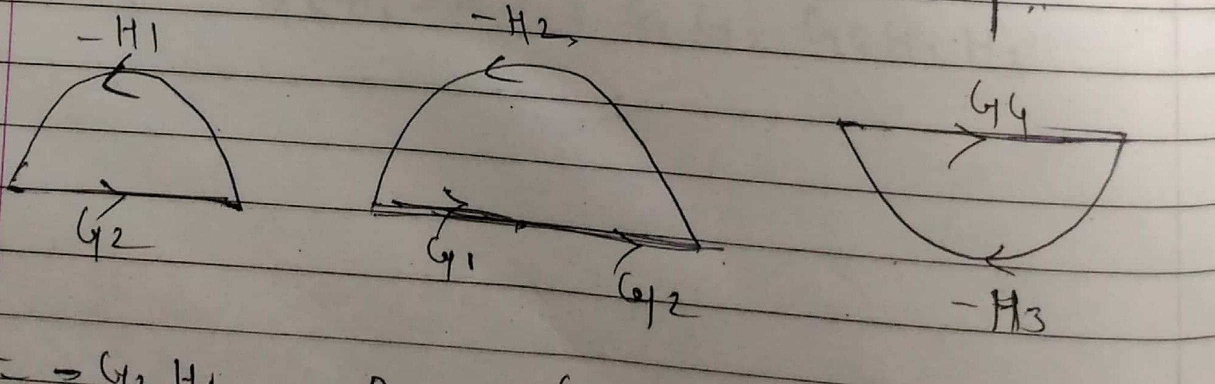
Q 2 -



Step 1) calculation of forward path

$P_1 = G_1 G_2 G_3 G_4 G_5$

Step 2 :) calculation of self loop.



$P_{11} = -G_2 H_1$ $\quad P_{21} = -G_1 G_2 H_2$ $\quad P_{31} = -G_4 H_3$

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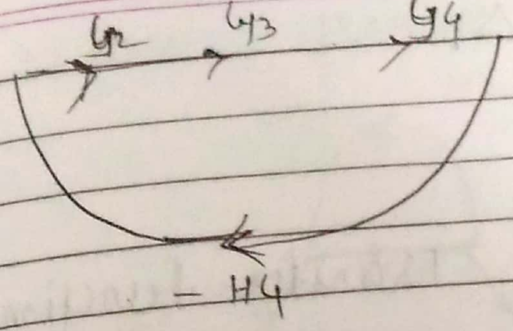

$P_{41} = -G_2 G_3 G_4 H_4$

Step 3:> Calculation of two non-touching loop

$P_{12} = P_{11} \times P_{31} = -G_2 H_1 \times -G_4 H_3$

$P_{12} = G_2 G_4 H_1 H_3$

$P_{22} = P_{21} \times P_{31} = -G_1 G_2 H_2 \times -G_4 H_3$

$P_{22} = G_1 G_2 G_4 H_2 H_3$

Step 4:- —

Step 5:> Calculation of Δ

$\Delta = 1 - \left[P_{11} + P_{21} + P_{31} + P_{41}\right] + \left[P_{12} + P_{22}\right]$

$\Delta = 1 + G_2 H_1 + G_1 G_2 H_2 + G_4 H_3 + G_2 G_3 G_4 \cancel{H_5} H_4$
$+ G_2 G_4 H_1 H_3 + G_1 G_2 G_4 H_2 H_3$

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Step 6:) Calculation of Δ_1

$$\Delta_1 = 1$$

Step 7):- Calculation of Transfer function

$$T.F. = \frac{C(s)}{R(s)}$$

$$= \frac{P_1 \Delta_1}{\Delta}$$

$$= \frac{G_1 G_2 G_3 G_4 G_5}{1 + G_2 H_1 + G_1 G_2 H_2 + G_4 H_3 + G_2 G_3 G_4 H_4 + G_2 G_4 H_1 H_3 + G_1 G_2 G_4 H_2 H_3}$$

$$T.F. = \frac{G_1 G_2 G_3 G_4 G_5}{1 + G_2 H_1 + G_1 G_2 H_2 + G_4 H_3 + G_2 G_3 G_4 H_4 + G_2 G_4 H_1 H_3 + G_1 G_2 G_4 H_2 H_3}$$

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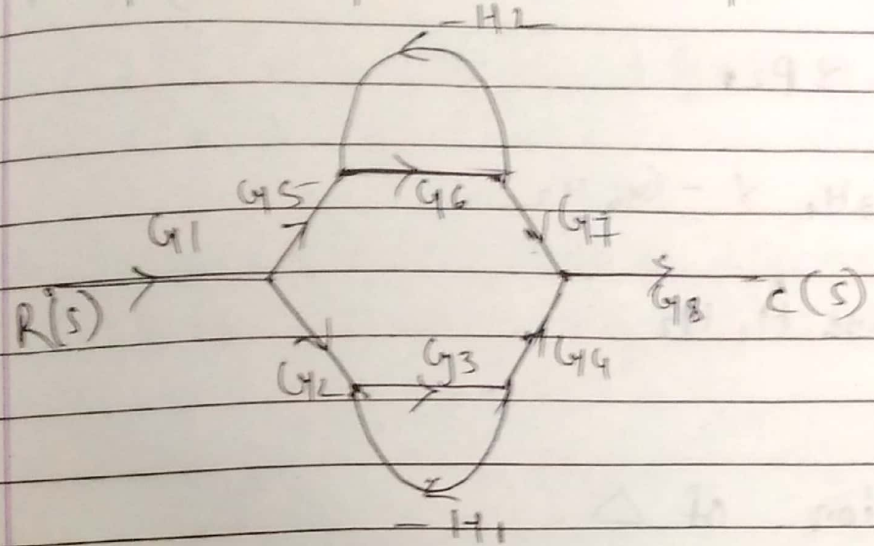
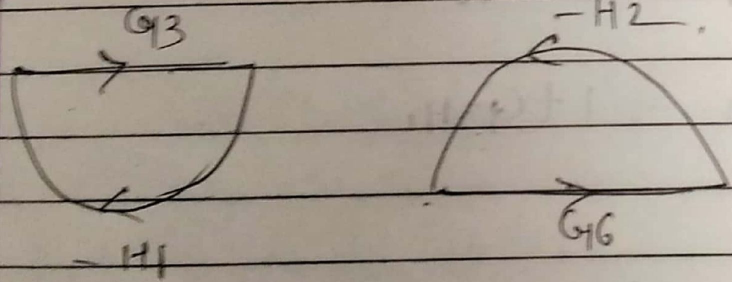
Q3 - obtain transfer function $\frac{C(s)}{R(s)}$



Step 1:) Calculation of forward path

$P_1 = G_1 G_2 G_3 G_4 G_8$ $\quad P_2 = G_1 G_5 G_6 G_7 G_8$

Step 2:) :- Calculation of self loop



$P_{11} = -G_3 H_1$ $\quad P_{21} = -G_6 H_2$

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Step3:> Calculation of two non-touching loop

$$P_{12} = P_{11} \times P_{21}$$

$$= -G_3H_1 \times -G_6H_2$$

$$P_{12} = G_3G_6H_1H_2$$

Step 5:> Calculation of Δ

$$\Delta = 1 - [P_{11} + P_{21}] + P_{12}$$

$$\Delta = 1 + G_3H_1 + G_6H_2 + G_3G_6H_1H_2$$

Step 6:> Calculation of Δ_1

$$\Delta_1 = 1 - P_{21} = 1 + G_6H_2$$

$$\Delta_2 = 1 - P_{11} = 1 + G_3H_1$$

Step 7:- Calculation of transfer function

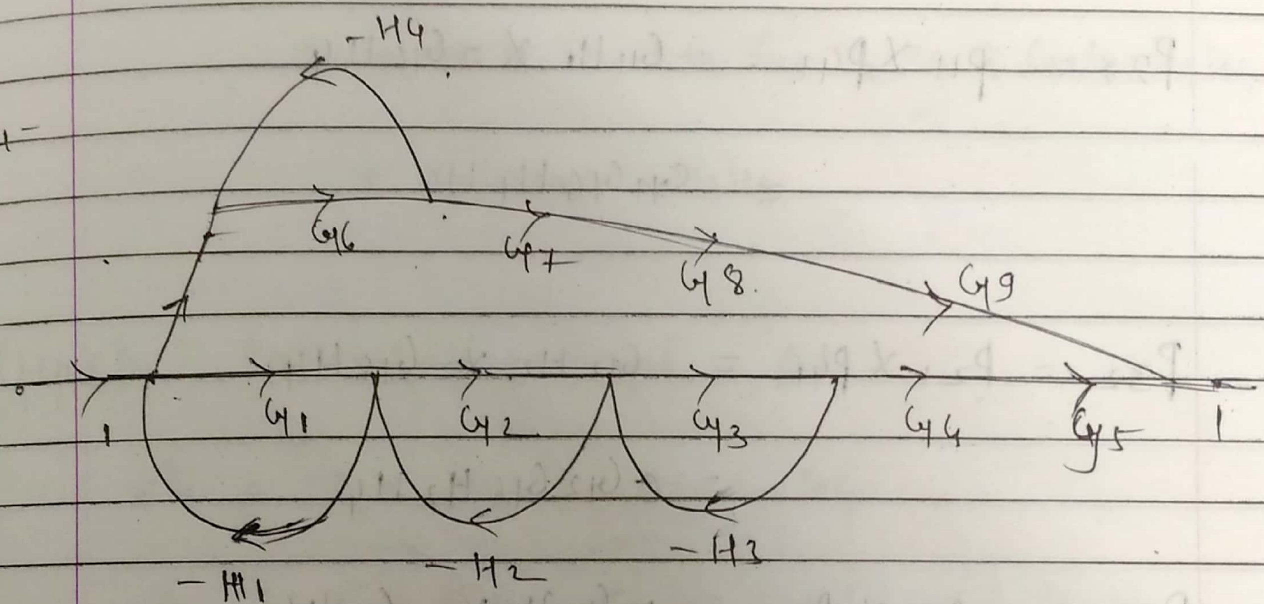
$$T.F. = \frac{C(s)}{R(s)}$$

$$= \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$$= \frac{G_1 G_2 G_3 G_4 G_8 + 1 + G_6 H_2 + G_1 G_5 G_6 G_7 G_8 1 + G_3 H_1}{1 + G_3 H_1 + G_6 H_2 + G_3 G_6 H_1 H_2}$$

$$T.F. = \frac{G_1 G_2 G_3 G_4 G_8 + 1 + G_6 H_2 + G_1 G_5 G_6 G_7 G_8 + 1 + G_3 H_1}{1 + G_3 H_1 + G_6 H_2 + G_3 G_6 H_1 H_2}$$

Q4-

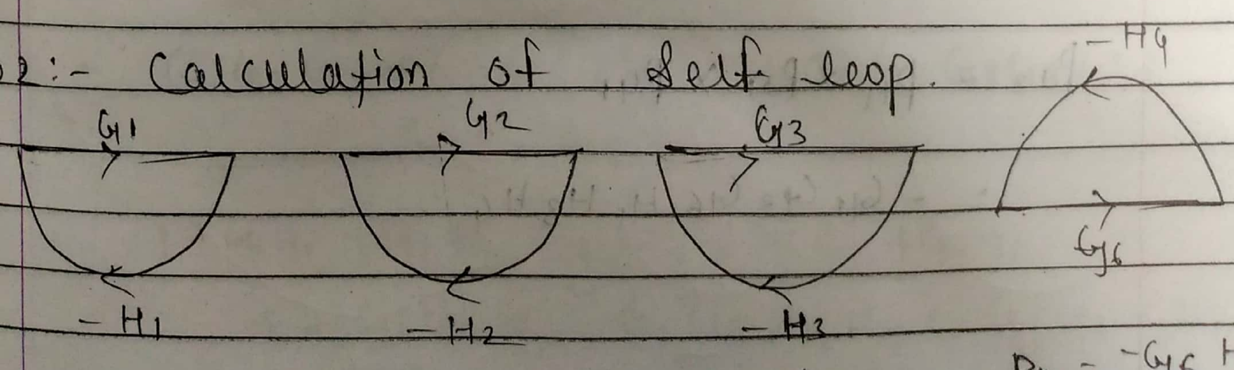


Step 1:- Calculation of forward path.

$P_1 = G_1 G_2 G_3 G_4 G_5$

$P_2 = G_6 G_7 G_8 G_9$

Step 2:- Calculation of self loop.



$P_{11} = -G_1 H_1$ $P_{21} = -G_2 H_2$ $P_{31} = -G_3 H_3$ $P_{41} = -G_6 H_4$

Step 3) Calculation of two non-touching loop.

$P_{12} = P_{11} \times P_{31} = -G_1 H_1 \times -G_3 H_3$

$= G_1 G_3 H_1 H_3$

$P_{22} = P_{11} \times P_{41} = -G_1 H_1 \times -G_6 H_4$

$= G_1 G_6 H_1 H_4$

$P_{32} = P_{21} \times P_{41} = -G_2 H_2 \times -G_6 H_4$

$= G_2 G_6 H_2 H_4$

$P_{42} = P_{31} \times P_{41} = -G_3 H_3 \times -G_6 H_4$

$= G_3 G_6 H_3 H_4$

Step 4) three non-touching loop.

$P_{13} = P_{11} \times P_{31} \times P_{41}$

$= -G_1 G_3 G_6 H_1 H_3 H_4$

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Step 5 → Calculation of Δ.

$$\Delta = 1 - [P_{11} + P_{21} + P_{31} + P_{41}] + [P_{12} + P_{22} + P_{32} + P_{42}] - P_{13}$$

$$\Delta = 1 + G_1H_1 + G_2H_2 + G_3H_3 + G_6H_4 + G_1G_3H_1H_3 + G_1G_6H_1H_4 + G_2G_6H_2H_4 + G_3G_6H_3H_4 + G_1G_3G_6H_1H_3H_4$$

Step 6 → Calculation of Δi

$$\Delta_1 = 1 - P_{41} = 1 + G_6H_4$$

$$\Delta_2 = 1 - P_{21} - P_{31} = 1 + G_2H_2 + G_3H_3$$

Step 7 → Calculation of T.F.

$$T.F. = \frac{C(s)}{R(s)} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$$= \frac{G_1G_2G_3G_4G_5 + 1 + G_6H_4 + G_6G_7G_8G_9 + 1 + G_2H_2 + G_3H_3}{1 + G_1H_1 + G_2H_2 + G_3H_3 + G_6H_4 + G_1G_3H_1H_3 + G_1G_6H_1H_4 + G_2G_6H_2H_4 + G_3G_6H_3H_4 + G_1G_3G_6H_1H_3H_4}$$

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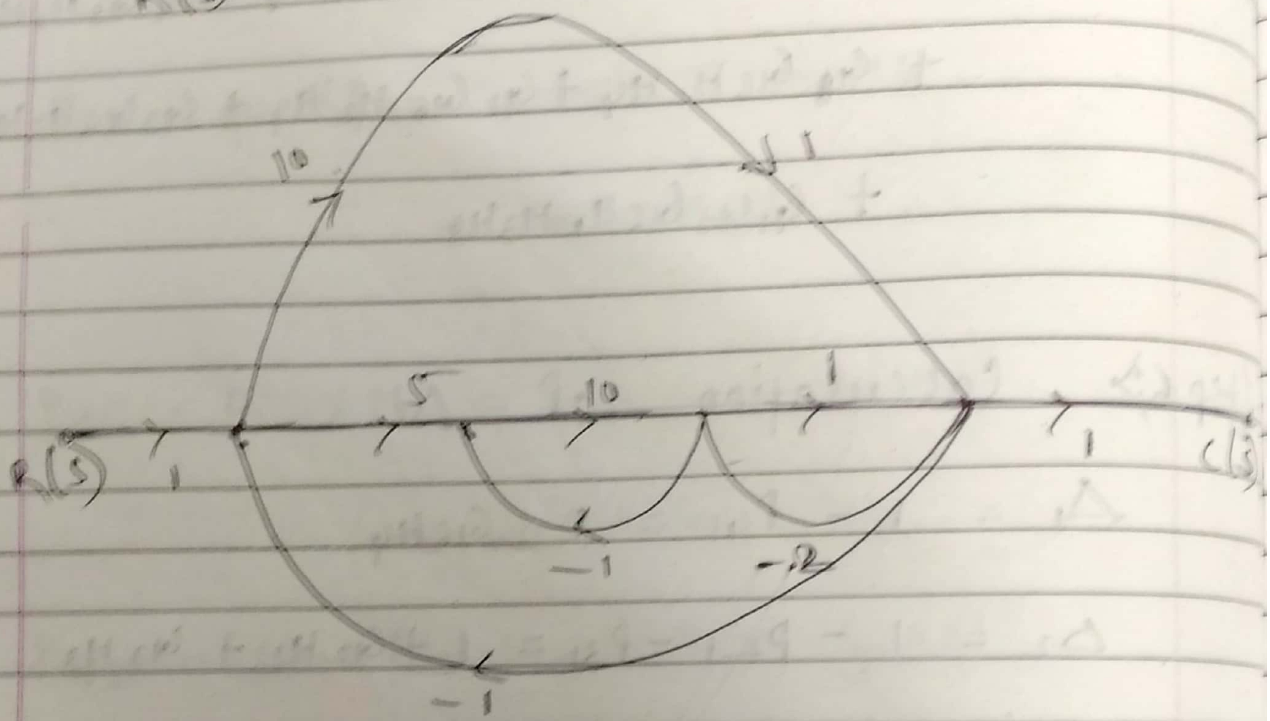
* Used Mason's gain formula
~~to find~~

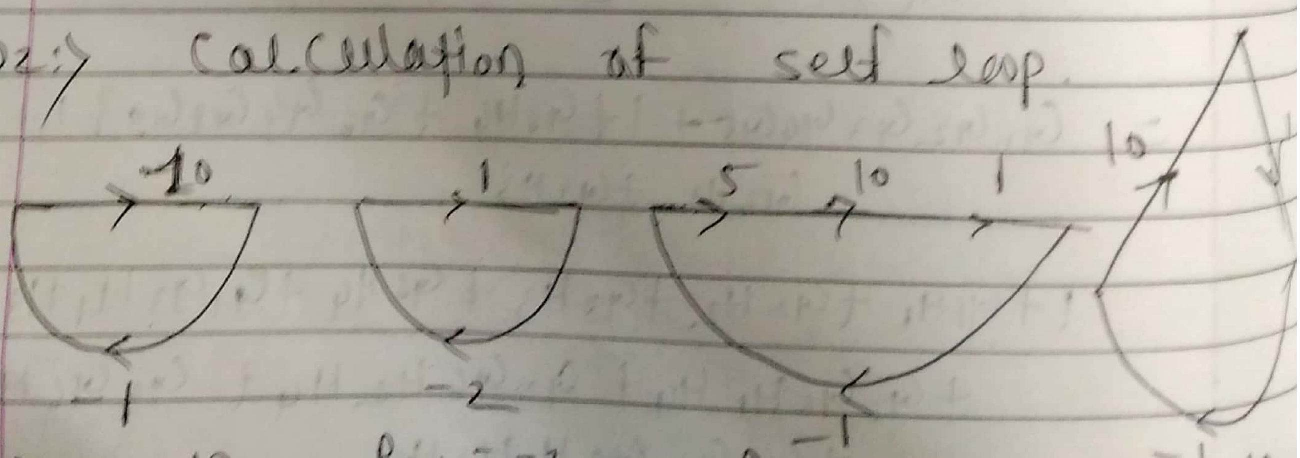
To find the transfer function
$\frac{C(s)}{R(s)}$



Step 1:- Calculation of forward path

$P_1 = 50$, $P_2 = 10$.

Step 2:> Calculation of self loop



$P_{11} = -10$. $P_{21} = -2$ $P_{31} = -50$ $P_{41} = -10$

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Step 3:- Calculation of two non - touching loop

$P_{12} = P_{11} \times P_{41}$
$P_{12} = -10 \times -10$
$= 100$

Step 4:- –

Step 5:- Calculation of Δ

$\Delta = 1 - [P_{11} + P_{21} + P_{31} + P_{41}] + P_{12}$

$= 1 + 10 + 2 + 50 + 10 + 100$

$\Delta = 173$

Step 6:- Calculation of Δi

$\Delta_1 = 1$

$\Delta_2 = 1 - P_{11} = 1 + 10$
$= 11$

Step 7:- Calculation of T.F.

$T.F. = \frac{C(s)}{R(s)} = \frac{P_1 \Delta_1 + P_2 \Delta_2}{\Delta}$

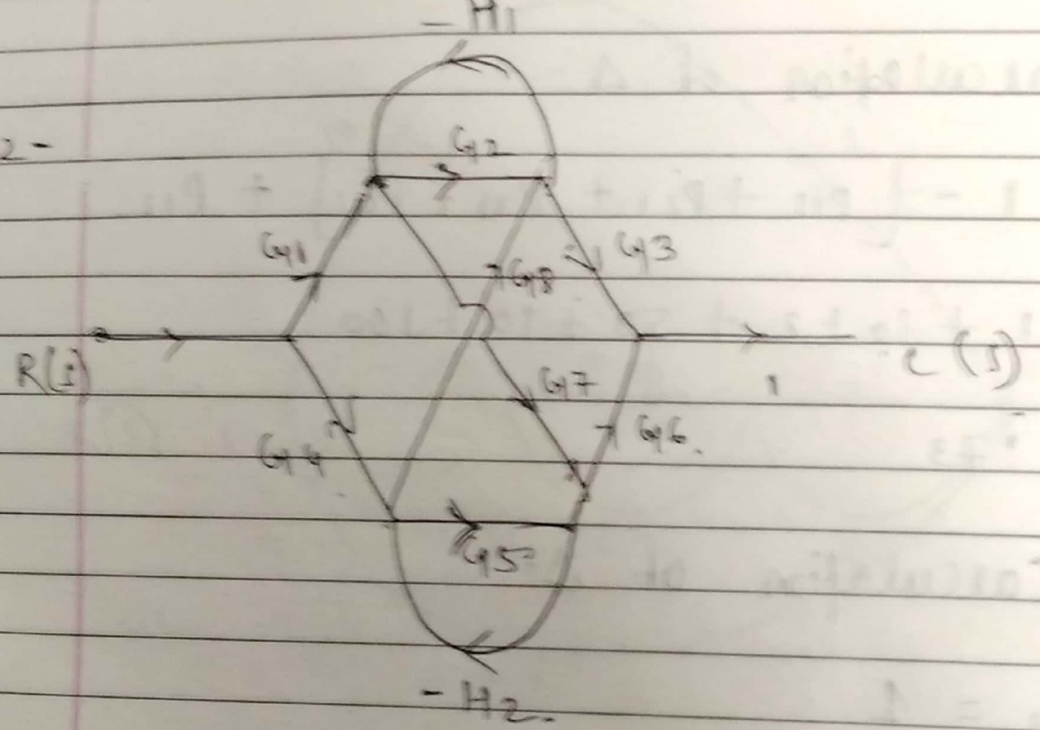
$= \frac{50 \times 1 + 10 \times 11}{173}$

$$= \frac{50 + 110}{173}$$

$$= \frac{160}{173}$$

$$T.F. = 0.9248$$

Q2 -



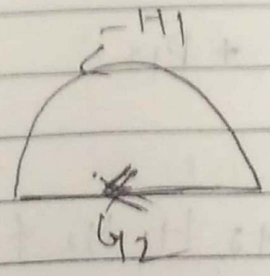
Step 1:- Calculation of forward path

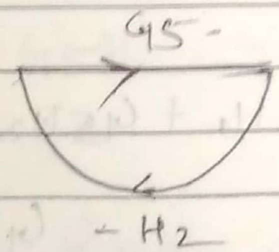
$P_1 = G_1 G_2 G_3$ $\quad P_2 = G_4 G_5 G_6$

$P_3 = G_1 G_6 G_7$ $\quad P_4 = G_3 G_4 G_8$

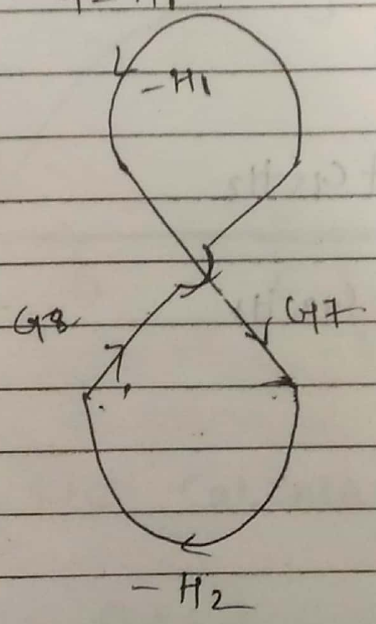
$P_5 = -G_1 G_3 G_7 G_8 H_2$ $\quad P_6 = -G_4 G_6 G_7 G_8 H_1$

Step 2 → Calculation of self loop.





$P_{11} = -G_2 H_1$ $\quad$ $P_{21} = -G_5 H_2$



$P_{31} = G_7 G_8 H_1 H_2$

Step 3 → Calculation of non-touching loop

$P_{12} = P_{11} \times P_{21}$

$= -G_2 H_1 \times -G_5 H_2$

$P_{12} = G_2 G_5 H_1 H_2$

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Step 5:> Calculation of Δ

$$\Delta = 1 - [P_{11} + P_{21} + P_{31}] + P_{12}$$

$$\Delta = 1 + G_2 H_1 + G_5 H_2 - G_7 G_8 H_1 H_2 + G_2 G_5 H_1 H_2$$

Step 6:> Calculation of Δ_i

$$\Delta_1 = 1 - P_{21} = 1 + G_5 H_2$$

$$\Delta_2 = 1 - P_{11} = 1 + G_2 H_1$$

$$\Delta_3 = 1$$

$$\Delta_4 = 1$$

$$\Delta_5 = 1$$

$$\Delta_6 = 1$$

Step 7:> Calculation of T.F.

$$T.F. = \frac{C(s)}{R(s)} = \frac{P_1\Delta_1 + P_2\Delta_2 + P_3\Delta_3 + P_4\Delta_4}{\Delta}$$

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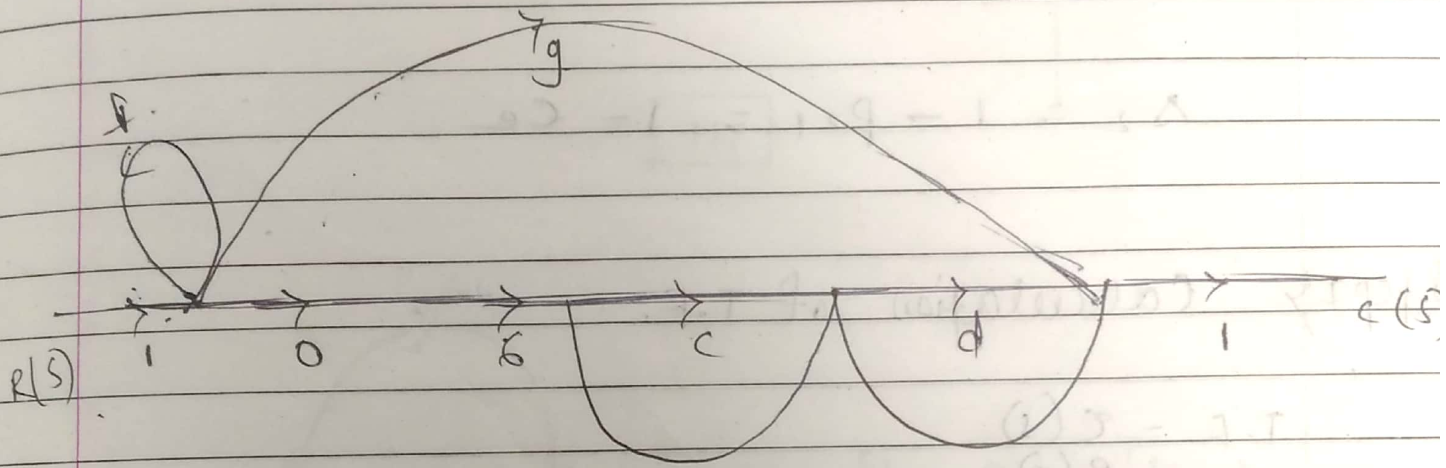
$$T.F. = \frac{G_1 G_2 G_3 + 1 + G_5 H_2 + G_4 G_5 G_6 + 1 + G_2 H_1 + G_1 G_6 G_7 + 1 + G_3 G_4 G_8 + 1}{1 + G_2 H_1 + G_5 H_2 - G_7 G_8 H_1 H_2 + G_2 G_5 H_1 H_2}$$

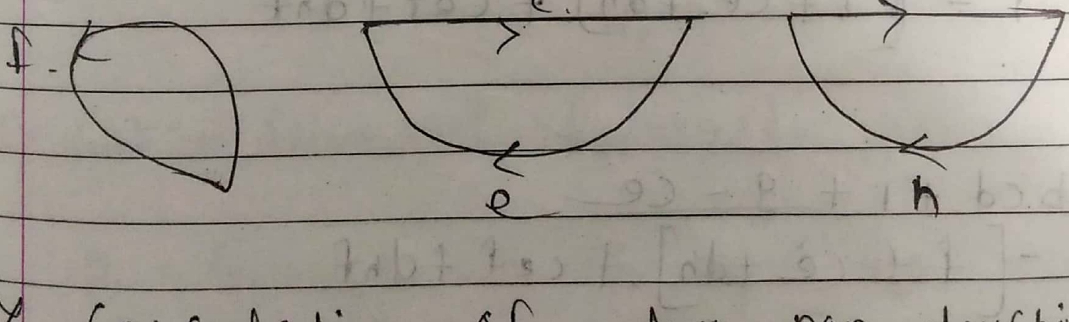
Q- Find $\frac{C(s)}{R(s)}$ using signal flow graph



Soln:- Step 1:- Calculation of forward path

$P_1 = abcd \qquad P_2 = g$

Step 2:- Calculation of self loop.



Step 3:- Calculation of two non-touching loop

$P_{12} = P_{11} \times P_{21} = f \times ce = cef$

$P_{22} = P_{11} \times P_{31} = f \times dh = dhf$

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Step 5:- Calculation of Δ

$$\Delta = 1 - [P_{11} + P_{21} + P_{31}] + [P_{12} + P_{12}]$$

$$\Delta = 1 - [f + ce + dh] + cef + dhf$$

Step 6:- Calculation of Δi

$$\Delta_1 = 1$$

$$\Delta_2 = 1 - P_{21} = 1 - ce$$

Step 7:- Calculation of T.F.

$$T.F. = \frac{C(s)}{R(s)}$$

$$= \frac{P_1 \Delta_1 + P_2 \Delta_2}{\Delta}$$

$$= \frac{abcd + 1 + g\,\cancel{tx} - ce}{1 - [f + ce + dh] + cef + dhf}$$

$$T.F. = \frac{abcd + 1 + g - ce}{1 - [f + ce + dh] + cef + dhf}$$

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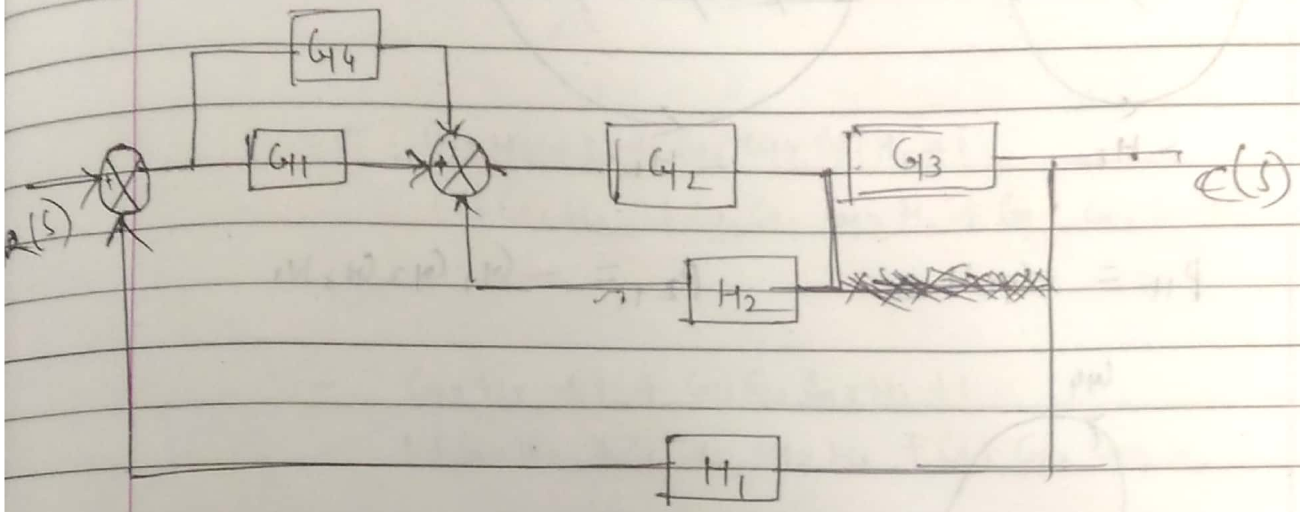
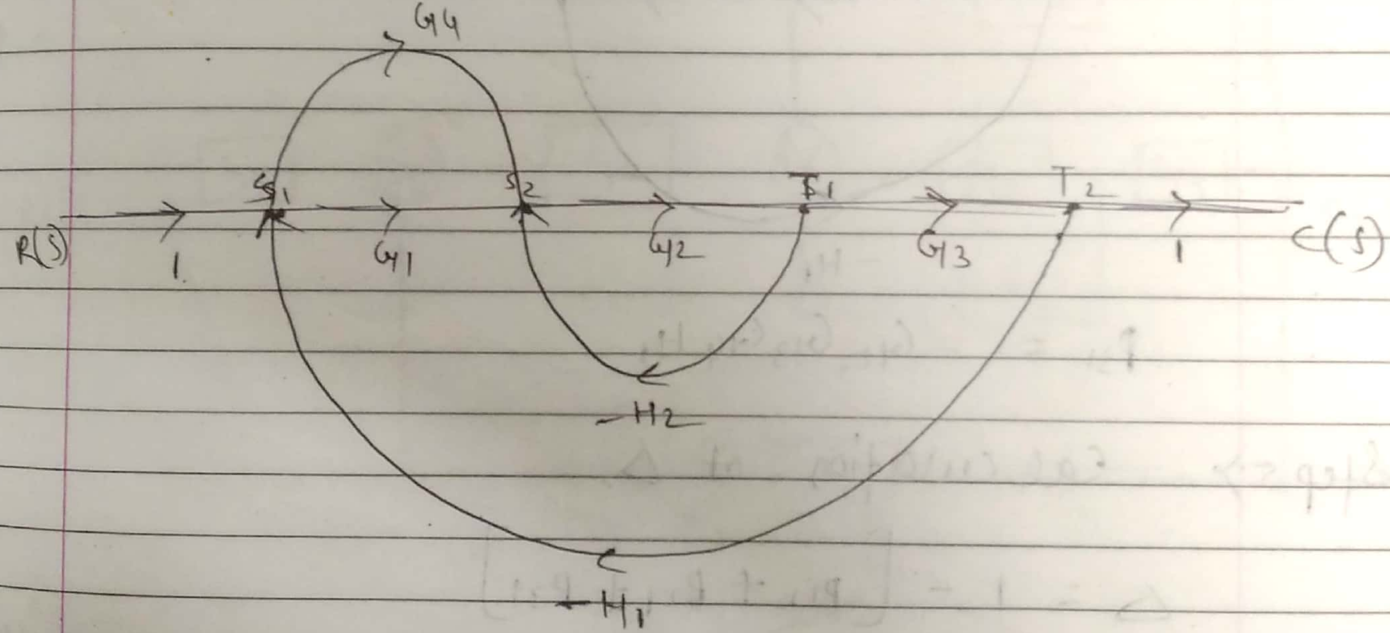
1) Each and every summing point define to node
2) Each and every take off pt. define to node
3) The summing point and take off point connected in series define to common node

Q- To obtain the transfer function from block diagram using SFG method.

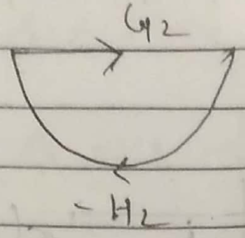


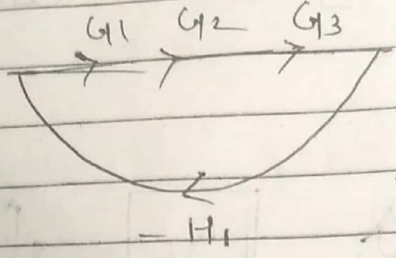


Step1) Calculation of forward path

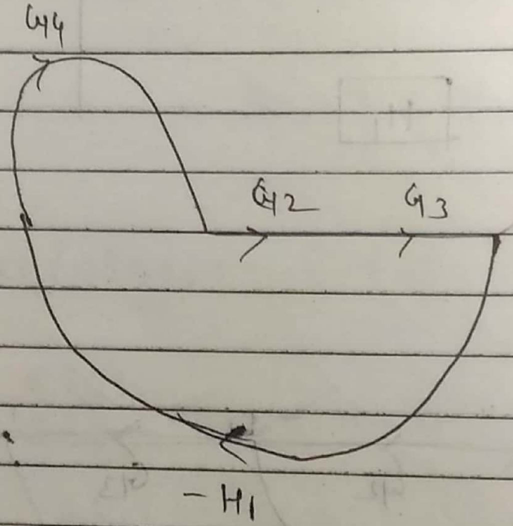
$P_1 = G_1 G_2 G_3$ $P_2 = G_4 G_2 G_3$

Step 4:- Calculation of self loop.





$P_{11} = -G_2 H_2$ $\qquad$ $P_{21} = -G_1 G_2 G_3 H_1$



$P_{31} = -G_2 G_3 G_4 H_1$

Step 5:- Calculation of Δ.

$$\Delta = 1 - [P_{11} + P_{21} + P_{31}]$$

$$\Delta = 1 + G_2 H_2 + G_1 G_2 G_3 H_1 + G_2 G_3 G_4 H_1$$

Step 6:- Calculation of Δ_i

$\Delta_1 = 1$

$\Delta_2 = 1$

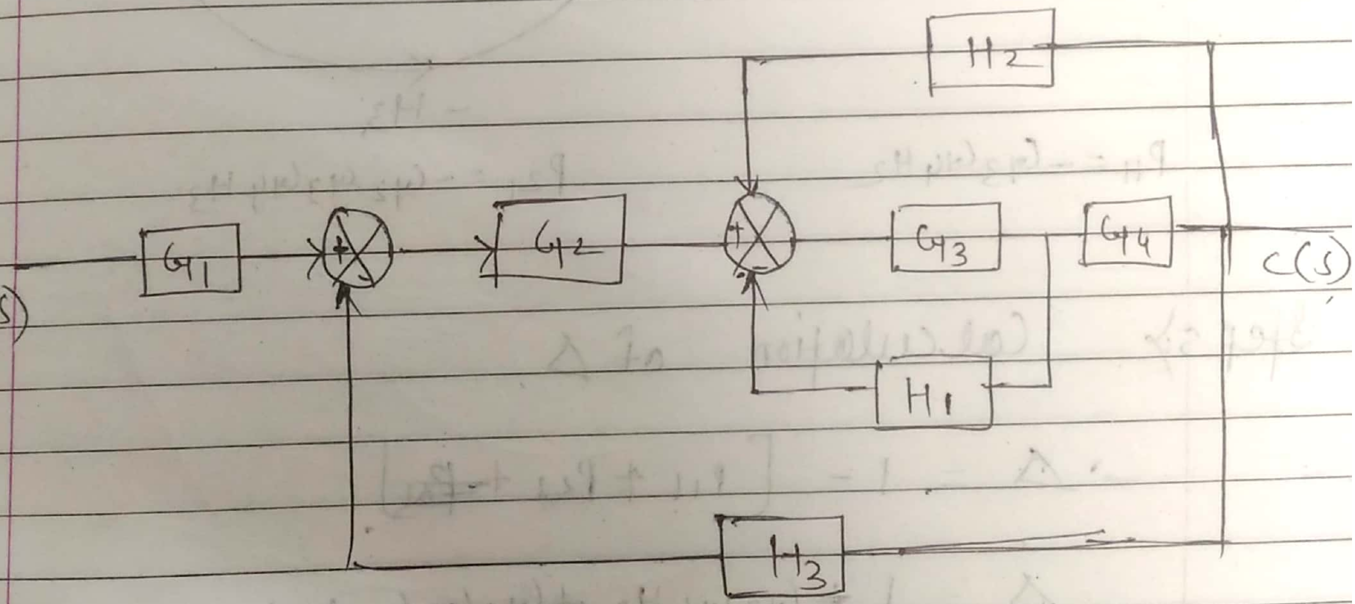
Step 7) Calculation of T.F.

$$T.F. = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

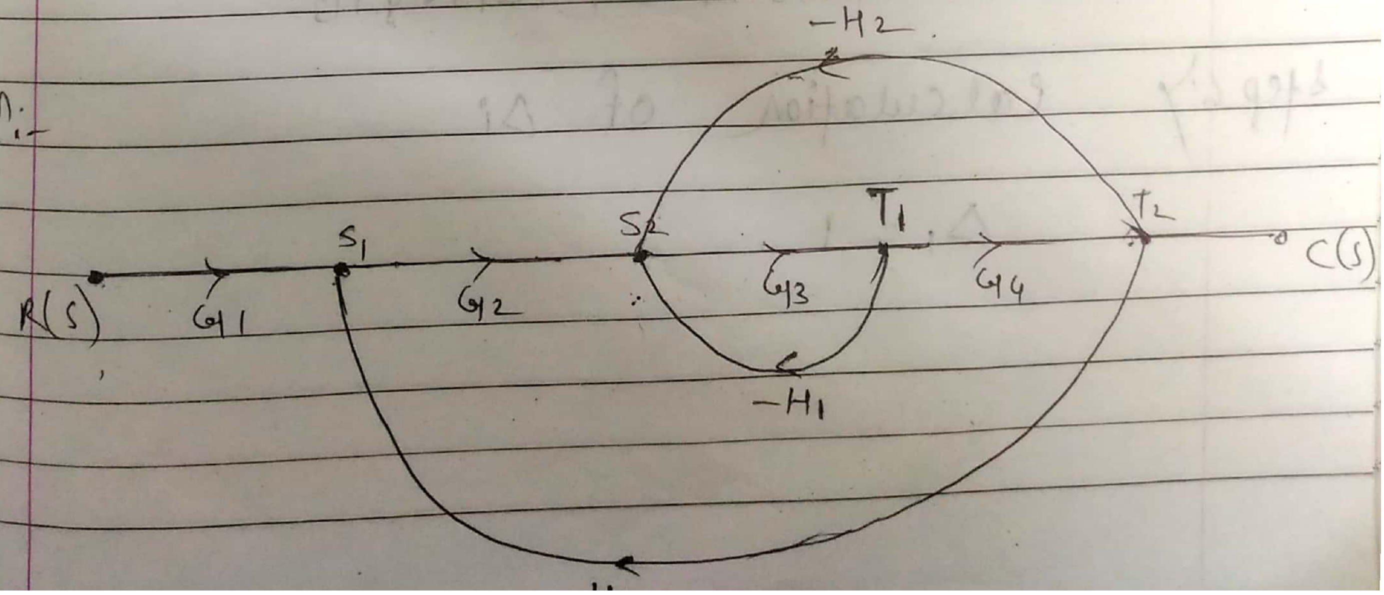
$$= \frac{G_2H_2 + 1 + G_1G_2G_3H_1 + 1}{1 + G_2H_2 + G_1G_2G_3H_1 + G_2G_3G_4H_1}$$

$$= \frac{G_2H_2 + 1 + G_1G_2G_3H_1 + 1}{1 + G_2H_2 + G_1G_2G_3H_1 + G_2G_3G_4H_1}$$

Q.



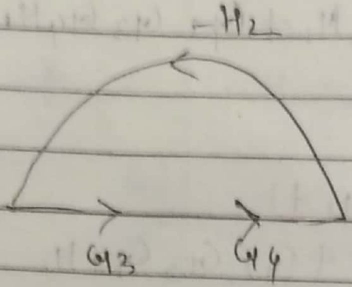
Sol^n:-

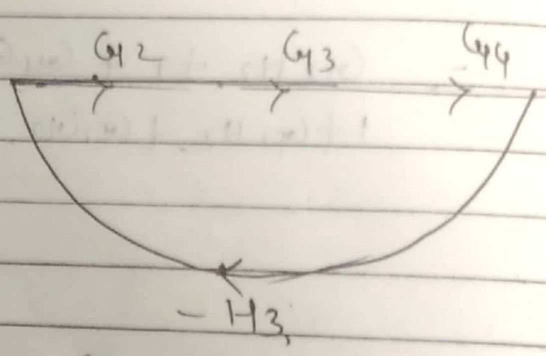


Step 1:- Calculation of forward path

$P_1 = G_1 G_2 G_3 G_4$

Step 2:- Calculation of self loop





$P_{11} = -G_3 G_4 H_2$

$P_{21} = -G_2 G_3 G_4 H_3$

Step 5:- Calculation of Δ.

$\Delta = 1 - [P_{11} + P_{21} + \cancel{P_{31}}]$.

$\Delta = 1 + G_3 G_4 H_2 + G_2 G_3 G_4 H_3$

Step 6:- Calculation of Δi.

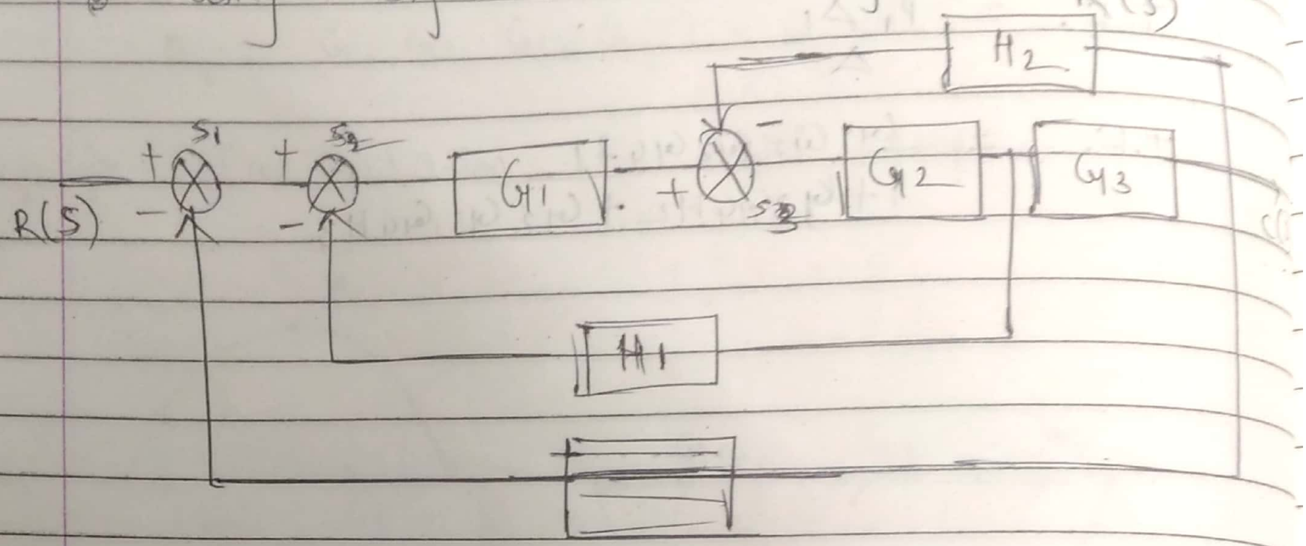
$\Delta_1 = 1$

Step 7) Calculation of T.F.

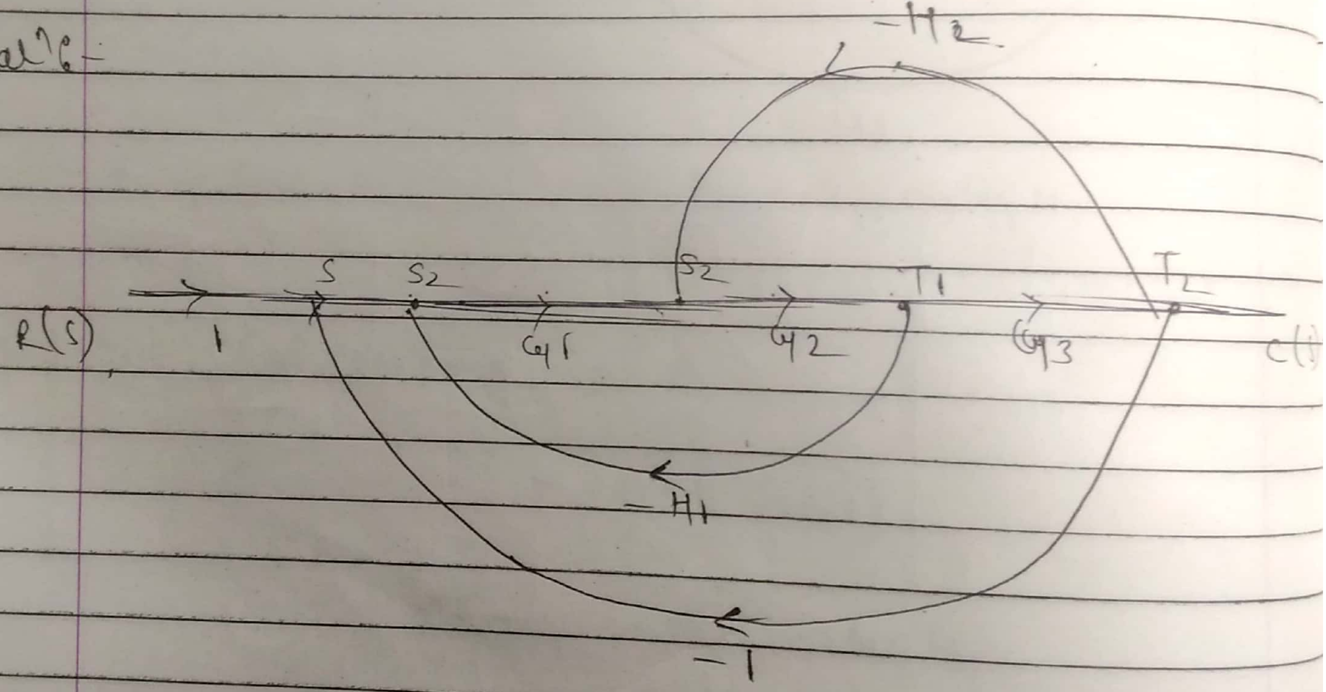
$$T.F. = \frac{P_1 \Delta_1}{\Delta}$$

$$T.F. = \frac{G_1 G_2 G_3 G_4 \cdot 1}{1 + G_3 G_4 H_2 + G_2 G_3 G_4 H_3}$$

Q- Determine the transfer function for using signal flow graph. $\frac{C(s)}{R(s)}$



Sol^n:-



Step 1:- Calculation of forward path.

$P_1 = G_1 G_2 G_3$.

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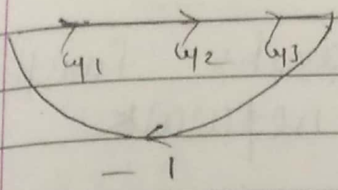
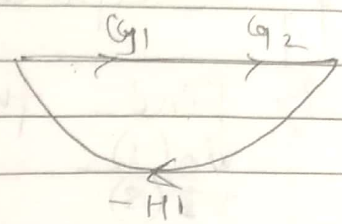
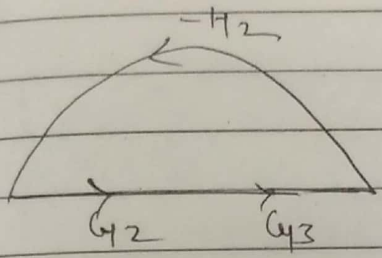
Step2:- Calculation of self loop.



$$P_{11} = -G_1 G_2 G_3$$



$$P_{21} = -G_1 G_2 H_1$$



$$P_{31} = -G_2 G_3 H_2$$

Step3:-

Step5:- Calculation of Δ.

$$\Delta = 1 - [P_{11} + P_{21} + P_{31}]$$

$$\Delta = 1 + G_1 G_2 G_3 + G_1 G_2 H_1 + G_2 G_3 H_2$$

Step6:- Calculation of Δ_1

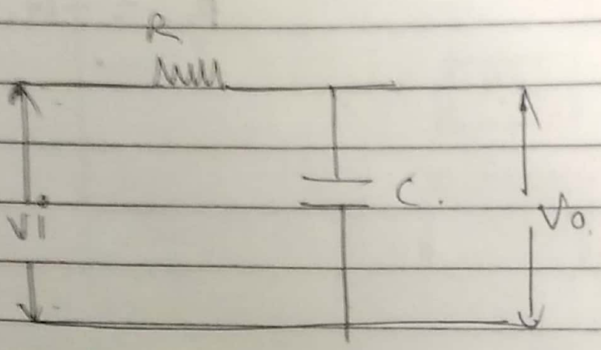
$$\Delta_1 = 1$$

Step7:- Calculation of T.F.

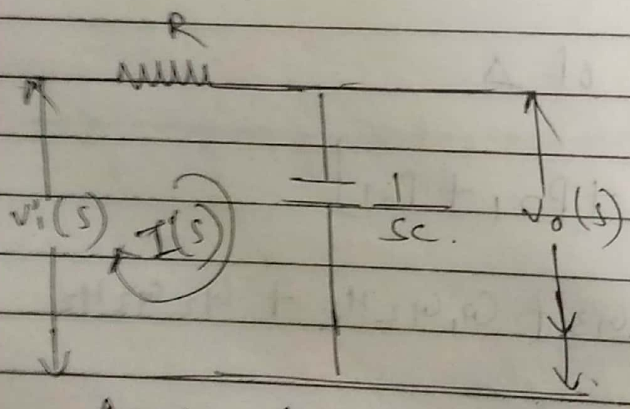
$$T.F. = \frac{C(s)}{R(s)} = \frac{P_1 \Delta_1}{\Delta} = \frac{G_1 G_2 G_3 + 1}{1 + G_1 G_2 G_3 + G_1 G_2 H_1 + G_2 G_3 H_2}$$

Electrical Network

1) Find the value of transfer function $\frac{V_o(s)}{V_I(s)}$ for the RC network



Convert s- domain.



Apply KVL

$$R\,I(s) + \frac{1}{SC}\,I(s) - V_i(s) = 0$$

$$V_i(s) = \left(R + \frac{1}{SC}\right) I(s)$$

$$V_i(s) = \frac{1 + SCR}{SC}\, I(s) \quad \text{--- (1)}$$

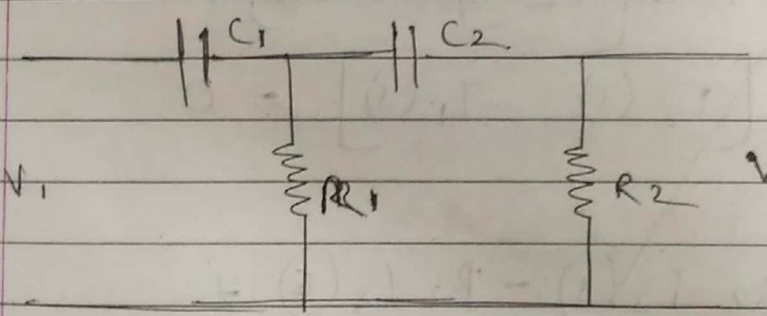
$$V_o(s) = \frac{1}{sC} I(s) \quad (2)$$

Divide eq^n (2) by (1)

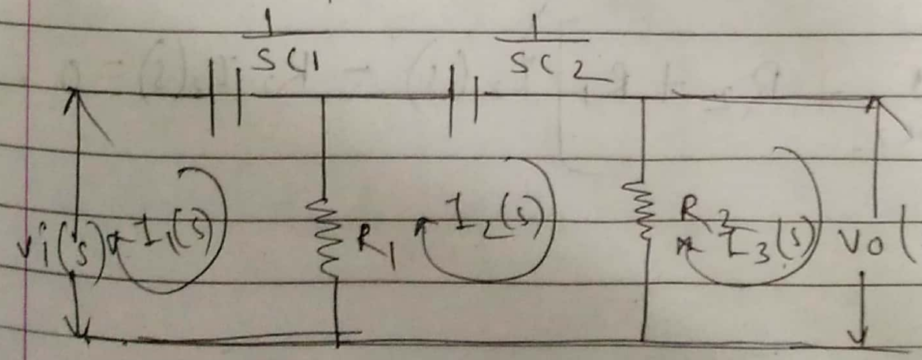
$$\frac{V_o(s)}{V_i(s)} = \frac{\frac{1}{\cancel{sC}} \cancel{I(s)}}{\frac{1+sCR}{\cancel{sC}} \cancel{I(s)}}$$

$$\boxed{\frac{V_o(s)}{V_i(s)} = \frac{1}{1+sCR}}$$

Q2- For the electrical network shown in fig. find the transfer function $\frac{V_o(s)}{V_i(s)}$



Sol^n:- Convert s- domain.



$$V_o(s) = R_2 I_2(s) \quad (1)$$

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Apply KVL at loop 1

$$\frac{1}{sc_1} I_1(s) + R_1 [I_1 - I_2] = V_i(s)$$

$$\frac{1}{sc_1} I_1(s) + R_1 [I_1(s) - I_2(s)] - V_i(s) = 0$$

$$\frac{1}{sc_1} I_1(s) + R_1 I_1(s) - R_1 I_2(s) = V_i(s)$$

$$\left[\frac{1}{sc_1} + R_1\right] I_1(s) - R_1 I_2(s) = V_i(s) \quad \text{—— 1}$$

$$V_i(s) = \left(R_1 + \frac{1}{sc_1}\right) I_1(s) - R_1 I_2(s) \quad 1$$

KVL at loop 2

$$\frac{1}{sC_2} I_2(s) + R_2 I_2(s) + R_1 \left[I_2(s) - I_1(s) \right] = 0.$$

$$-R_1 I_1(s) + \left(R_1 + R_2 + \frac{1}{sC_2} \right) I_2(s) = 0.$$

$$\left(R_1 + R_2 \frac{1}{sC_2} \right) I_2(s) = R_1 I_1(s)$$

$$I_2(s) = \frac{R_1}{\left(R_1 + R_2 + \frac{1}{sC_2} \right)} I_1(s)$$

$$I_2(s) = \frac{R_1}{\frac{1 + sC_2 (R_1 + R_2)}{sC_2}} I_1(s)$$

$$I_2(s) = \frac{sC_2 R_1}{1 + sC_2 (R_1 + R_2)} I_1(s) \quad \text{—— (3)}$$

Substitute eq^n (3) in eq^n (1) and (2)

$$V_0(s) = \frac{R_2 \times sC_2 R_1}{1 + sC_2 (R_1 + R_2)} I_1(s) \quad \text{—— (4)}$$

$$V_i(s) = \left[R_1 + \frac{1}{sC_1} \right] I_1(s) - \frac{R_1 \times sC_2 R_1}{1 + sC_2 (R_1 + R_2)} I_1(s)$$

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$$V_1(s)\left[\left(\frac{1+sC_1R_1}{sC_1}\right)-\frac{sC_2R_1^2}{1+sC_2(R_1+R_2)}\right]I_1(s)$$

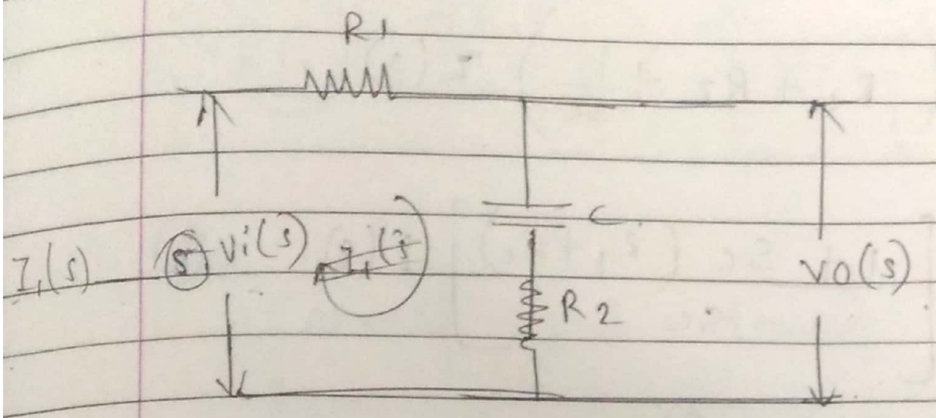
$$Vi(s)=\frac{(1+sC_1R_1)(1+sC_2(R_1+R_2))-s^2C_1C_2R_1^2}{sC_1(1+sC_2(R_1+R_2))}$$ (A)

divide eq^n (4) and (5)

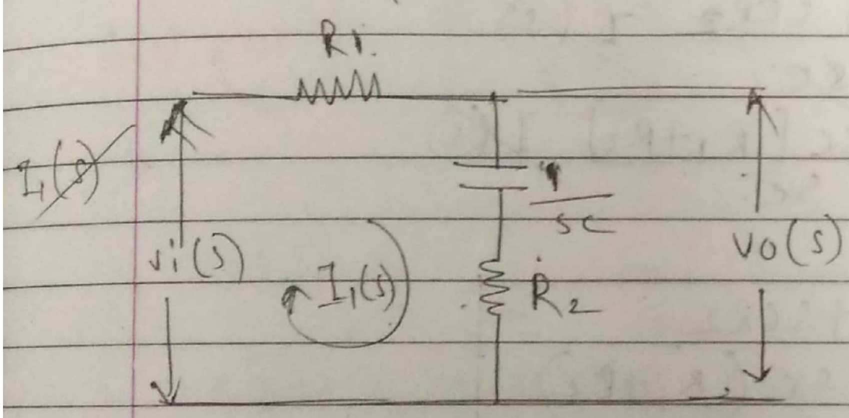
$$\frac{V_0(s)}{Vi(s)}=\frac{\dfrac{sC_2R_1R_2}{\cancel{1+sC_2(R_1+R_2)}}\cancel{I_1(s)}}{\dfrac{(1+sC_1R_1)(1+sC_2(R_1+R_2))-s^2C_1C_2R_1^2}{sC_1\left[\cancel{1+sC_2(R_1+R_2)}\right]}}$$

$$\frac{V_0(s)}{Vi(s)}=\frac{s^2C_1C_2R_1R_2}{(1+sC_1R_1)(1+sC_2(R_1+R_2))-s^2C_1C_2R_1^2}$$

Q- Find the transfer function for the network as shown in fig.



Sol^n. Convert s - domain



$$V_o(s) = \left[R_2 + \frac{1}{sC}\right] I(s)$$

$$V_o(s) = \left[\frac{1 + sCR_2}{sC}\right] I(s) \quad \text{--- (1)}$$

Apply KVL at loop (1)

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$$R_1 I(s) + \left[\frac{1}{sC} + R_2\right] I(s) - v_i(s) = 0$$

$$v_i(s) = \left(R_1 + R_2 + \frac{1}{sC}\right) I(s)$$

$$v_i(s) = \left[\frac{1 + sC(R_1 + R_2)}{sC}\right] I(s) \quad \text{—— (2)}$$

divide eqn (2) by (1)

$$\frac{v_o(s)}{v_i(s)} = \frac{\dfrac{1 + sCR_2}{\cancel{sC}}\,\cancel{I(s)}}{\dfrac{1 + sC[R_1 + R_2]}{\cancel{sC}}\,\cancel{I(s)}}$$

$$\boxed{\frac{v_o(s)}{v_i(s)} = \frac{1 + sCR_2}{1 + sC(R_1 + R_2)}}$$

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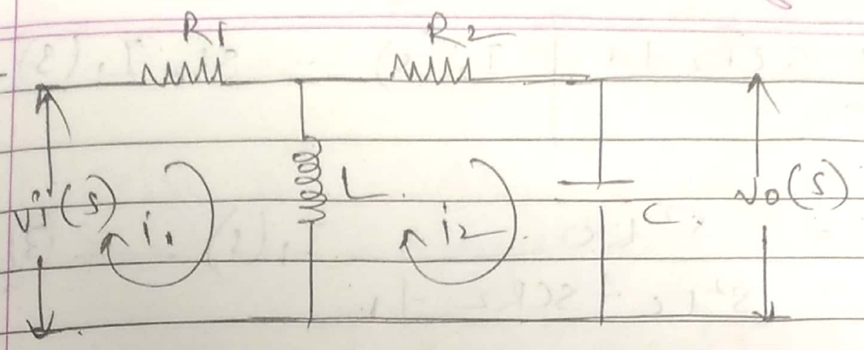
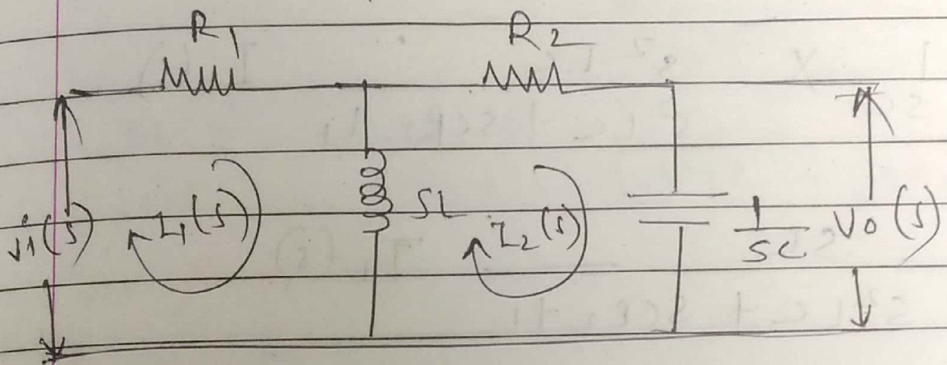
Q2 -



Sol^n:- Convert s - domain



$$V_o(s) = \frac{1}{sC} I_2(s) \quad \text{—— (1)}$$

Apply KVL at loop (1) and (2)

Loop (1):- $R_1 I_1(s) + sL\left[I_1(s) - I_2(s)\right] - V_i(s) = 0$

$$V_i(s) = \left[R_1 + sL\right] I_1(s) - sL\, I_2(s) \quad \text{—— (2)}$$

Loop (2):- $R_2 I_2(s) + \frac{1}{sC} I_2(s) + sL\left[I_2(s) - I_1(s)\right] = 0$

$$-sL\, I_1(s) + \left[R_2 + sL + \frac{1}{sC}\right] I_2(s) = 0$$

$$\left[R_2 + sL + \frac{1}{sC}\right] I_2(s) = sL\, I_1(s)$$

$$\left[\frac{s^2LC + sCR_2 + 1}{sC}\right] I_2(s) = sL\, I_1(s)$$

$$I_2(s) = \frac{s^2LC}{s^2LC + sCR_2 + 1} I_1(s) \quad (3)$$

Substitute eqn (3) in eqn (1) and (2)

$$V_0(s) = \frac{1}{sC} \times \frac{s^2LC}{s^2LC + sCR_2 + 1} I_1(s)$$

$$V_0(s) = \frac{sL}{s^2LC + sCR_2 + 1} I_1(s)$$

$$V_i(s) = (R_1 + sL) I_1(s) - \frac{sL \times s^2LC}{s^2LC + sCR_2 + 1} I_1(s)$$

$$\left[(R_1 + sL) - \frac{s^3L^2C}{s^2LC + sCR_2 + 1}\right] I_1(s)$$

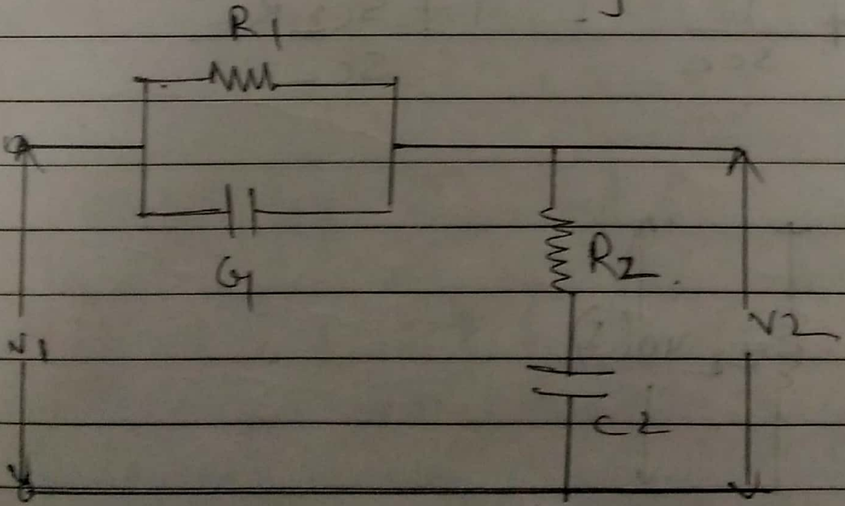
$$V_i(s) = \frac{(R_1 + sL)(s^2LC + sCR_2 + 1) - s^3L^2C}{(s^2LC + sCR_2 + 1)} I_1(s) \quad (5)$$

divide eqⁿ (4) by (5).

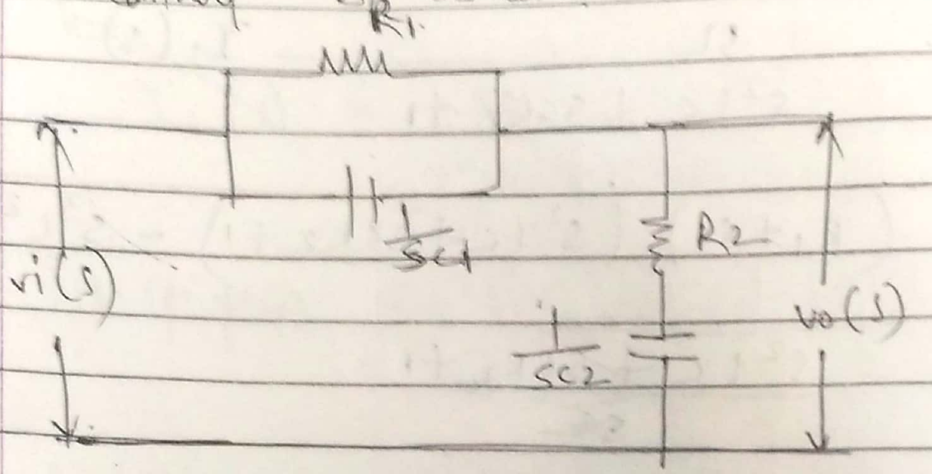
$$\frac{V_o(s)}{v_i(s)} = \frac{\dfrac{sL}{s^2LC + sCR_2 + 1} \cancel{I_1(s)}}{\dfrac{(R_1 + sL)(s^2LC + sCR_2 + 1) - s^3L^2C}{\dfrac{s^2LC + sCR_2 + 1}{\cancel{sL}}} \cancel{I_1(s)}}$$

$$\boxed{\frac{V_o(s)}{v_i(s)} = \frac{sL}{(R_1 + sL)(s^2LC + sCR_2 + 1) - s^3L^2C}}$$

Q3- Find the transfer function for the n/w. Shown in fig.



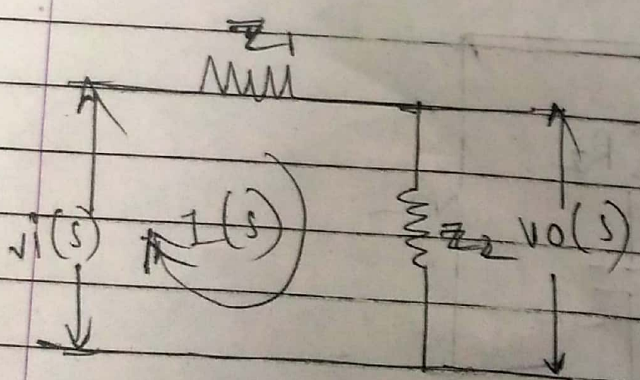
Sol^n: Convert S-domain



$$Z_1 = R_1 \parallel \frac{1}{sC_1}$$

$$= \frac{R \times \frac{1}{sC_1}}{R + \frac{1}{sC_1}} = \frac{R_1}{1 + sC_1R_1}$$

$$Z_2 = R_2 + \frac{1}{sC_2} = \frac{1 + sC_2R_2}{sC_2}$$



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$$V_o(s) = Z_2 I(s)$$

$$V_o(s) = \frac{1 + sC_2R_2}{sC_2}$$

Apply KVL at loop 1

$$Z_1 I_1(s) + Z_2 I(s) - Vi(s) = 0$$

$$Vi(s) = (Z_1 + Z_2) I(s)$$

$$= \left[\frac{R_1}{1 + sC_1R_1} + \frac{1 + sC_2R_2}{sC_2}\right] I(s)$$

$$= \frac{sC_2R_1 + (1 + sC_2R_2)(1 + sC_1R_1)}{sC_2[1 + sC_1R_1]} I(s)$$

$$Vi(s) = \frac{sC_2R_1 + (1 + sC_2R_2)(1 + sC_1R_1)}{sC_2[1 + sC_1R_1]} I(s) \quad \text{--- (2)}$$

divide eqn (1) and (2).

$$\frac{V_o(s)}{Vi(s)} = \frac{\dfrac{1 + sC_2R_2}{\cancel{sC_2}} \cancel{I(s)}}{\dfrac{sC_2R_1 + (1 + sC_2R_2)(1 + sC_1R_1)}{\cancel{sC_2}[1 + sC_1R_1]} \cancel{I(s)}}$$

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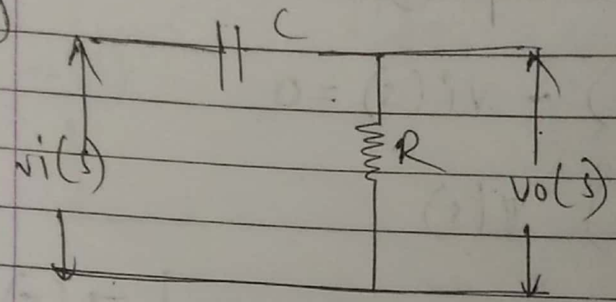
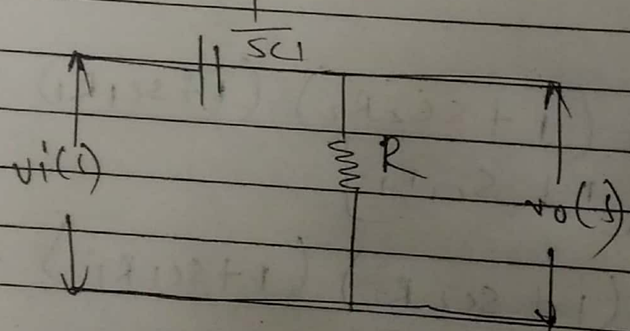
$$\frac{V_o(s)}{V_i(s)} = \frac{(1+sC_2R_2)(1+sC_1R_1)}{sC_2R_1 + (1+sC_2R_2)(1+sC_1R_1)}$$

(4)



Sol^n:- Convert s - domain



$$v_o(s) = R\,I(s) \quad \text{--- } (1)$$

Apply KVL at loop (A)

$$\frac{1}{sC} I(s) + R\,[\,I(s) - v_i(s) = 0$$

$$v_i(s) = \left(R + \frac{1}{sC}\right) I(s)$$

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$$vi(s) = \frac{1+sCR}{sC} I(s) \quad \text{—— ②}$$

divide eqn ① by ②

$$\frac{vo(s)}{vi(s)} = \frac{R I \cancel{(s)}}{\frac{1+sCR}{sC} I \cancel{(s)}}$$

$$\boxed{\frac{vo(s)}{vi(s)} = \frac{sCR}{1+sCR}}$$

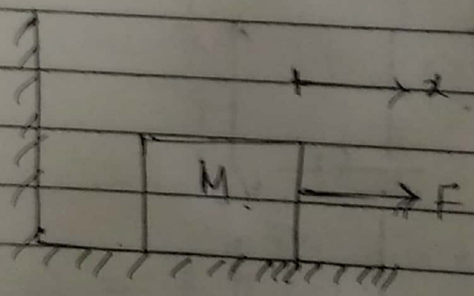
Modelling of mechanical System

There are two types of modelling

i) Translational
ii) Rotational

i) Mass
ii) Damper
iii) Spring

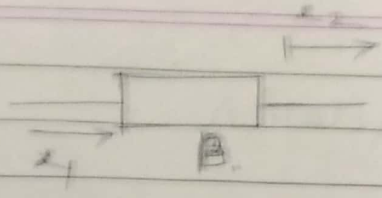
i) Mass :- The physical model of a mass element assumed. Mass is connected as the center of the body objects



$$F = M \cdot x\, a$$

$$F = M \frac{d^2x}{dt^2}$$

2) Damper :- It is the friction between moving surface separated by fluid. or solid body medium and it is proportional to the velocity



$F \propto v$

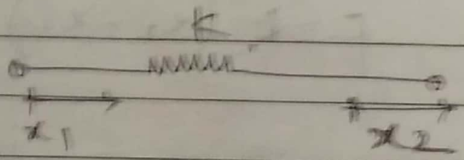
$F \propto v$

$F = B.v.$

$$F = B.\frac{dx}{dt}$$

$$F = B.\frac{d}{dx}(x_1 - x_2)$$

Spring :-



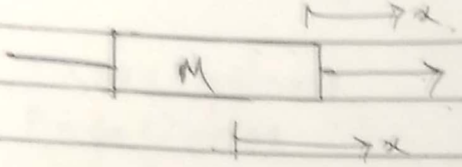
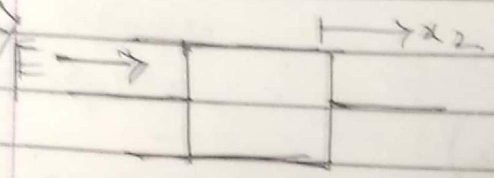
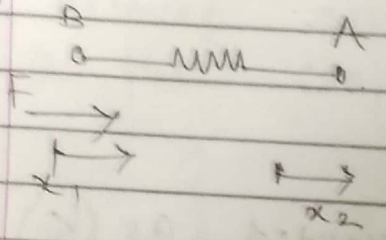
Spring constant and denoted as (k)

The body is subjected to force under the goes elastic deformation. It is proportional to the distance.

$F \propto x.$

$F = k.x$

$F = k(x_1 - x_2)$

Sr. No.	Element	Relation	
1)		$F = M.\frac{d^2x}{dt^2}$	Mass
2)		$F = B.\frac{d}{dt}(x_1 - x_2)$	Damper
3)		$F = K(x_1 - x_2)$	Spring

* Force voltage Analogy

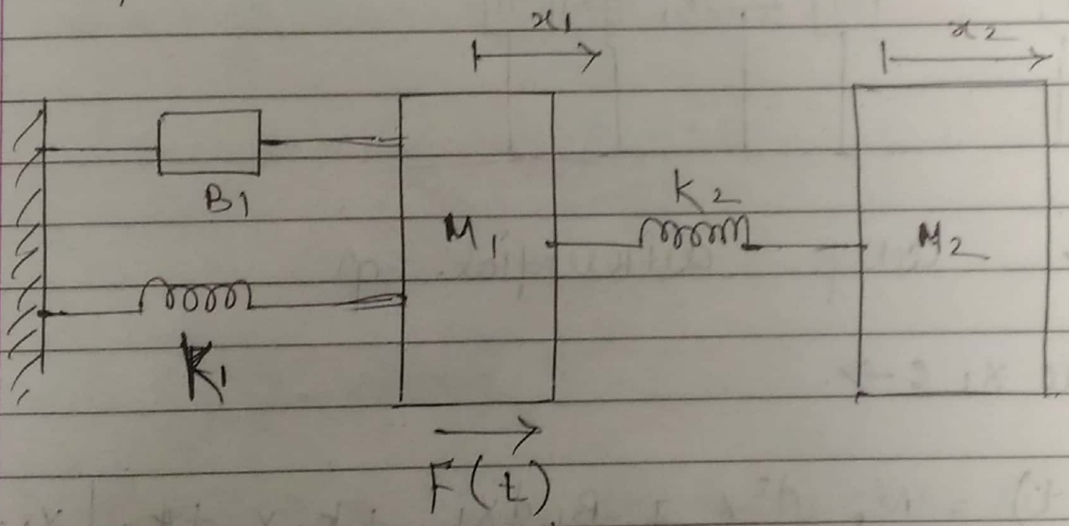
	Translational	Electrical	Rotational
1)	Force (F)	Voltage (V)	Torque (T)
2)	Mass (M)	Inductance (L)	Inertia (J)
3)	Damper (B)	Resistance (R)	Damper (B)
4)	Spring (K)	Elasticity $= \frac{1}{C}$	Spring (K)

5) Displacement		Charge (q)		Displacement

6) Velocity		Current $i = \frac{dq}{dt}$		Velocity

Q1 - For the mechanical system shown in fig.

(A) Draw the mechanical network
(B) Write the differential eqn of performance
(C) Draw the force voltage analogues network



Soln - Step 1 :- no. of nodes = no. of displacement
$n = 2$

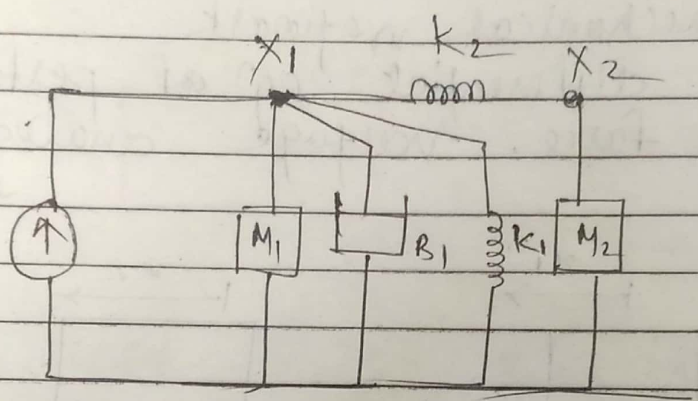
Step 2 :- (1) Mass
M_1 is Connected to x_1
M_2 is Connected to x_2

(2) Damper
B_1 is Connected betn reference and x_1

(2) Spring

k_1 is connected between reference and x_1
k_2 is connected betn x_1 and x_2

Step 3:) Draw mechanical network



Step 4:) write differential eqn

node x_1 :→

$$f(t) = M_1 \frac{d^2x}{dt^2} + B_1 \frac{dx_1}{dt} + k_1 x_1 + k_2 [x_1 - x_2]$$

take Laplace transform

$$F(s) = s^2 M_1 X_1(s) + sB_1 X_1(s) + k_1 X_1(s) + k_2 [X_1(s) - X_2(s)] \quad \text{--- (1)}$$

node : 2>

$$M_2 \frac{d^2 x_2}{dt^2} + k_2 [x_2 - x_1] = 0$$

take Laplace transform.

$$s^2 M_2 X_2(s) + k_2 [X_2(s) - X_1(s)] = 0 \quad \text{--- (2)}$$

Step 5> Force voltage Analogy

$F \rightarrow V$. $M \rightarrow L$ $B \rightarrow R$ $k \rightarrow \frac{1}{C}$

$x \rightarrow q$ $i = \frac{dq}{dt}$

$$I(s) = s \cdot q(s)$$

$$q(s) = \frac{I(s)}{s}$$

Now eq^n (1) becomes

$$F(s) = s^2 M_1 X_1(s) + s B_1 X_1(s) + k_1 X_1(s) + k_2 [X_1(s) - X_2(s)]$$

$$V(s) = s^2 L_1 \times \frac{I_1(s)}{s} + s R_1 \times \frac{I_1(s)}{s} + \frac{1}{C_1} \frac{I_1(s)}{s} + \frac{1}{C_2} \left[\frac{I_1(s)}{s} - \frac{I_2(s)}{s} \right]$$

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$$= sL_1 I_1(s) + R_1 I_1(s) + \frac{1}{sC_1} I_1(s) + \frac{1}{sC_2} I_1(s)$$
$$- \frac{1}{sC_2} I_2(s)$$

$$V(s) = \left[R_1 + sL_1 + \frac{1}{sC_1} + \frac{1}{sC_2}\right] I_1(s) - \frac{1}{sC_2} I_2(s) \quad \text{--- (3)}$$

Now eqn (2) becomes.

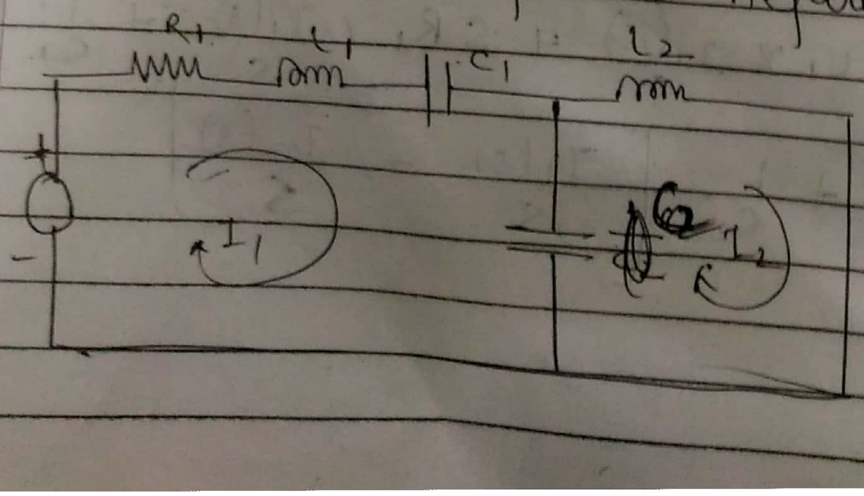
$$s^2 M_2 X_2(s) + K_2 \left[X_2(s) - X_1(s)\right] = 0$$

$$s^2 \times L_2 \times \frac{I_2(s)}{s} + \frac{1}{C_2} \left[\frac{I_2(s)}{s} - \frac{I_1(s)}{s}\right] = 0$$

$$sL_2 I_2(s) + \frac{1}{sC_2} I_2(s) - \frac{1}{sC_2} I_1(s) = 0$$

$$-\frac{1}{sC_2} I_1(s) + \left(sL_2 + \frac{1}{sC_2}\right) I_2(s) = 0$$

Step 6:- Draw electrical network



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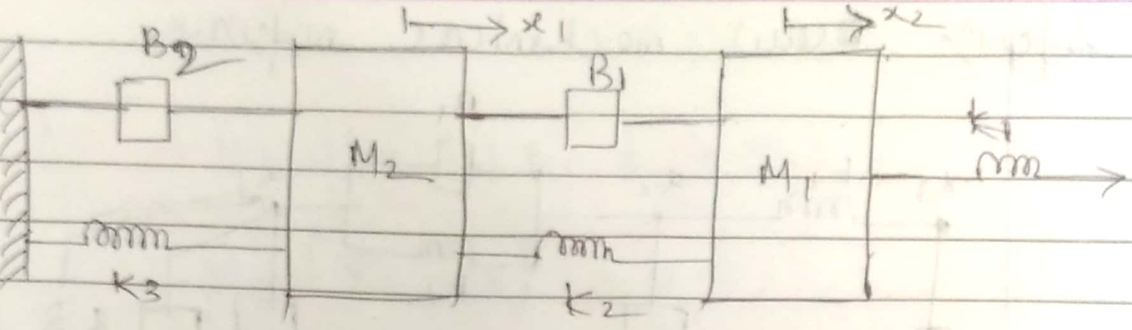


Soln:- Step1: no. of nodes = no. of displacement

$\boxed{n = 3}$

Step2:- i) Mass

M_1 is Connected to x_2

M_2 is Connected to x_1

2) Damper

B_1 is Connected betn x_1 and x_2

B_2 is Connected betn x_1 and reference

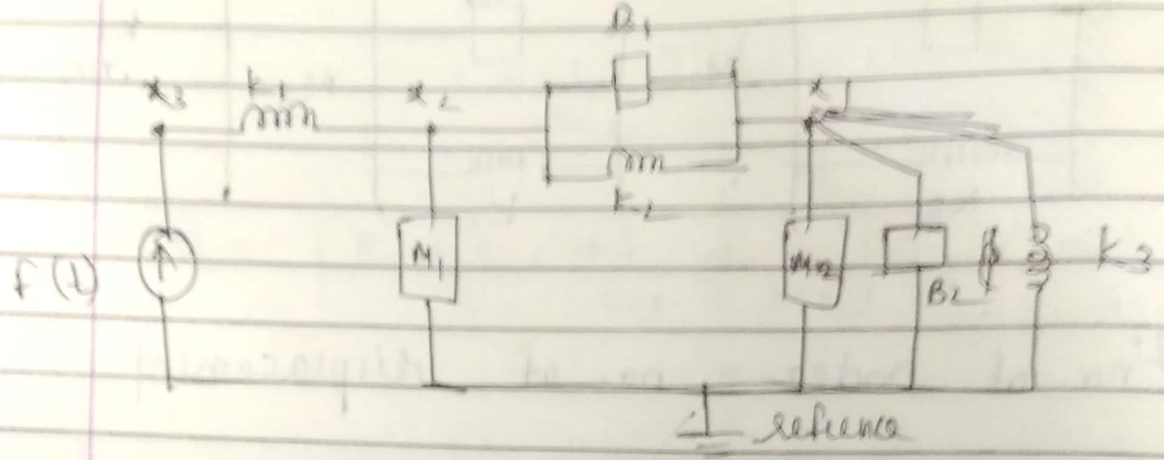
3) Spring

K_1 is Connected betn x_2 and x_3

K_2 is Connected betn x_1 and x_2

K_3 is Connected betn x_1 and reference.

Step 3:> Draw mechanical network.



Step 4:> write differential eqn

node:1> $f(t) = k_1 \; (x_3 - x_2)$

take. L.T.

$$F(s) = k_1 \left[x_3(s) - x_2(s) \right] \quad \text{—— (1)}$$

node:2>

$$k_1 (x_2 - x_3) + M_1 \frac{d^2 x_2}{dt^2} + B_1 \frac{d(x_2 - x_1)}{dt} + k_2 \left[x_2 - x_1 \right] = 0$$

take. L.T.

$$k_1 \left[X_2(s) - X_3(s) \right] + s^2 M_1 X_2(s) + sB_1 \left[X_2(s) - X_1(s) \right]$$
$$+ k_2 \left[X_2(s) - X_1(s) \right] = 0 \quad \text{—— (2)}$$

node (1)

$$k_3 x_1 + B_2 \frac{dx_1}{dt} + M_2 \frac{d^2 x_1}{dt^2} + B_1 \frac{d(x_1 - x_2)}{dt} +$$
$$K_2 [x_1 - x_2] = 0$$

take L.T.

$$k_3 X_1(s) + sB_2 X_1(s) + s^2 M_2 X_1(s) + sB_1 [X_1(s) - X_2(s)]$$
$$+ k_2 [X_1(s) - X_2(s)] = 0 \quad \text{——} (3)$$

Step(5) Force voltage Analogy

$F \longleftrightarrow V \quad M \longleftrightarrow L \quad B \longleftrightarrow R \quad K = \frac{1}{C} \quad X \longrightarrow q$

$$i = \frac{dq}{dt}$$

$$I(s) = s\,q(s)$$
$$q(s) = \frac{I(s)}{s}$$

Now eq^n (1) becomes

$$F(s) = \frac{1}{C_1} \left[\frac{\cancel{k_3} I_3(s)}{s} - \frac{I_2(s)}{s} \right]$$
$$= \frac{1}{sC_1} I_3(s) - \frac{1}{sC_2} I_2(s)$$

$$\therefore -\frac{1}{sC_1} I_2(s) + \frac{1}{sC_1} I_3(s) = V(s) \quad \text{——} (4)$$

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Now eq^n (2) becomes

$$K_1\left[x_2(s) - x_3(s)\right] + s^2 M_1\, x_2(s) + sB_1\left(x_2(s) - x_1(s)\right)$$

$$+ K_2\left[x_2(s) - x_1(s)\right] = 0$$

$$\frac{1}{C_1}\left[\frac{I_2(s)}{s} - \frac{I_3(s)}{s}\right] + s^2 L\, \frac{I_2(s)}{\cancel{s}} + \cancel{s} B_1\left[\frac{I_2(s)}{\cancel{s}} - \frac{I_1(s)}{s}\right]$$

$$+ \frac{1}{C_2}\left[\frac{I_2(s)}{s} - \frac{I_1(s)}{s}\right] = 0 \quad (5)$$

~~v(s) =~~ [

$$\left[\frac{1}{sC_1} I_2(s) - \frac{1}{sC_2} I_3(s)\right] + s^2 L \frac{I_2(s)}{s} +$$

sB_1 [

$$\frac{1}{C_1}\left(\frac{1}{sC_1} I_2(s) - \frac{1}{sC_2} I_3(s)\right] + s\, L\, I_2(s) +$$

$$B_1\left[I_2(s) - \frac{I_1(s)}{s}\right] + \frac{1}{C_2}\left[\frac{I_2(s)}{s} - \frac{I_1(s)}{s}\right] = 0$$

$$-\left[R_1 + \frac{1}{sC_2}\right] I_1(s) + \left[R_1 + sL_1 + \frac{1}{sC_1} + \frac{1}{sC_2}\right]$$

$$I_2(s) - \frac{1}{sC_1} I_3(s) = 0 \quad \text{——} \quad (5)$$

Now eq^n (3) becomes.

$$\frac{1}{C_3}\frac{I_1(s)}{s} + sR_2\frac{I_1(s)}{s} + s^2L_2\frac{I_1(s)}{s} +$$

$$sR_1\left[\frac{I_1(s)}{s} - \frac{I_2(s)}{s}\right] + \frac{1}{C_2}\left[\frac{I_1(s)}{s} - \frac{I_2(s)}{s}\right] = 0$$

$$\left[R_1 + R_2 + sL_2 + \frac{1}{sC_2} + \frac{1}{sC_3}\right] I_1(s) -$$

$$\left[R_1 + \frac{1}{sC_2}\right] I_2(s) = 0 \quad \text{——} \quad (6)$$

~~Step 6:~~ Electrical network.