07/VII

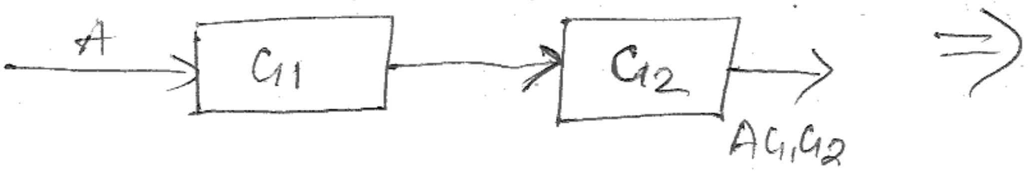
Block Diagram Reduction :-

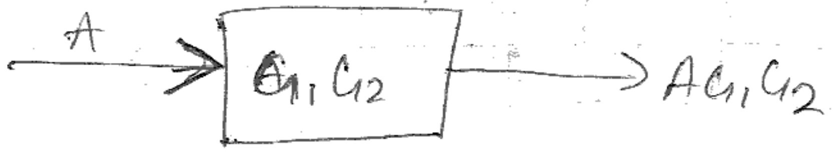
Block diagram can be reduced to find the overall transfer function of the system.

The following rules can be used for Block diagram Reduction :-

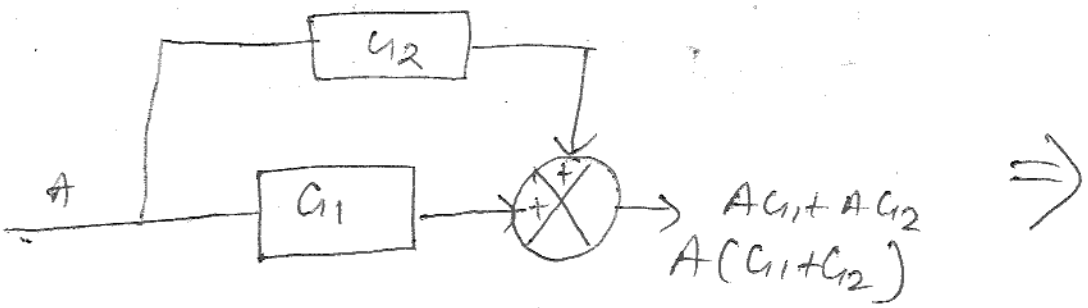
The rules are framed such that any modification in the diagram doesnot alter the output and input.

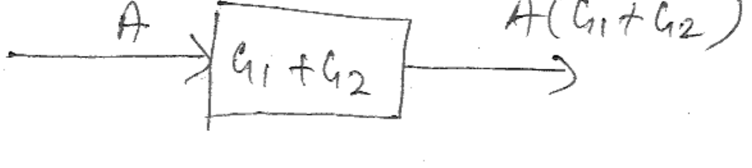
Rule 1 :- Combination of blocks in cascade



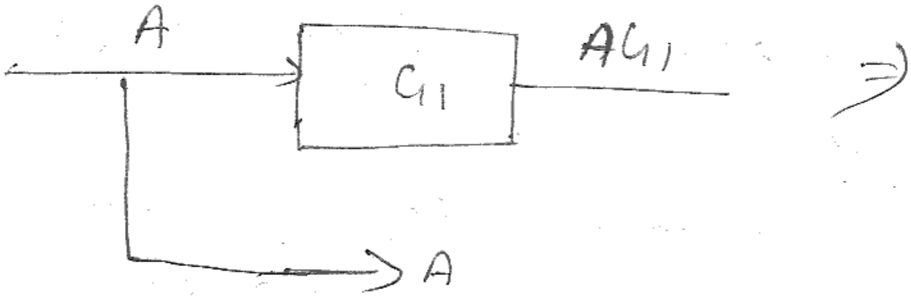


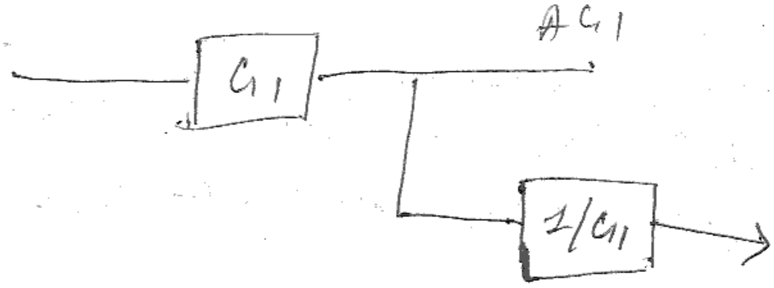
2. Combination of blocks in parallel



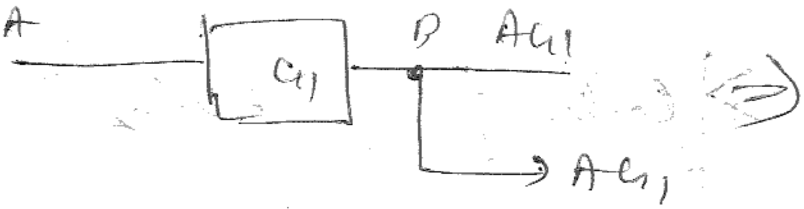


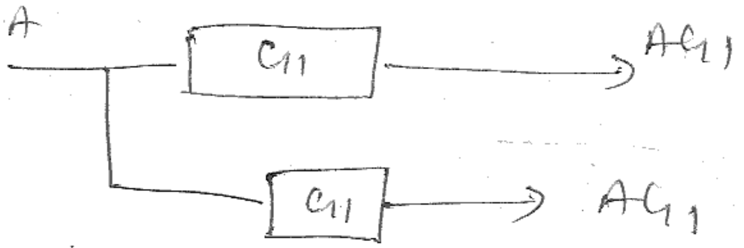
3. Moving the branch point ahead of the block.



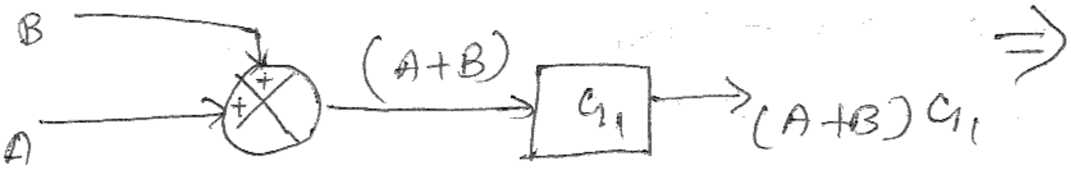


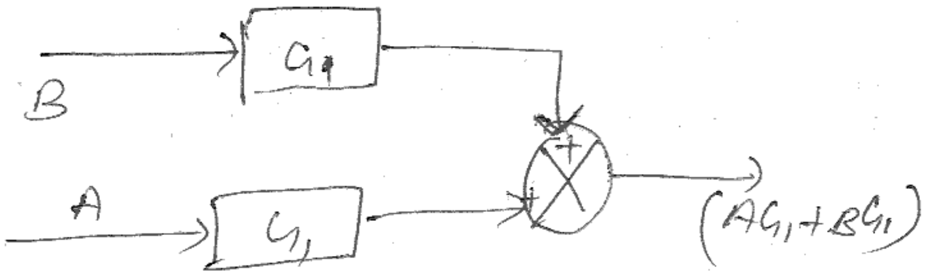
4. Moving the branch point before a block





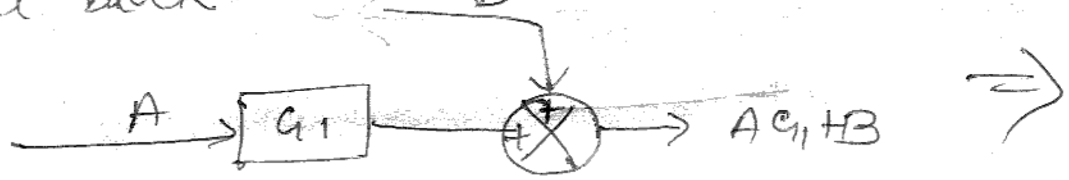
ahead 5. Moving a summing point ahead of a block.

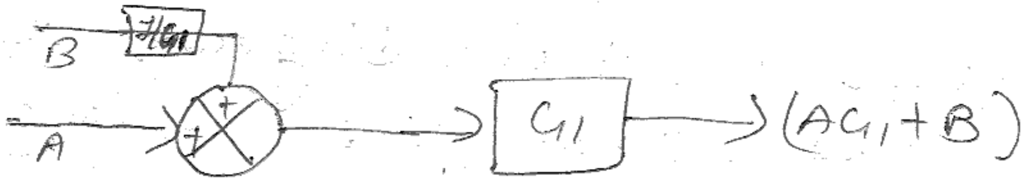




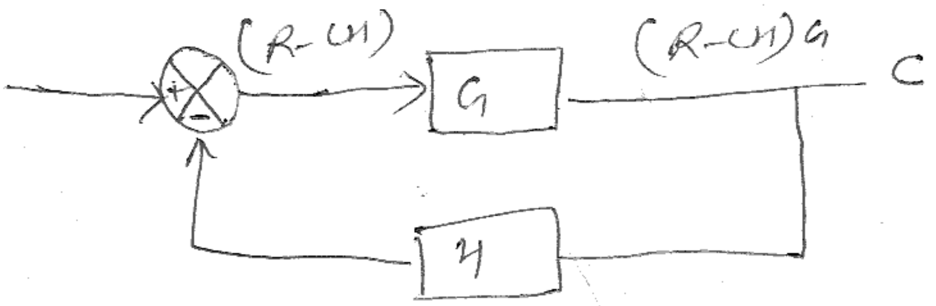
fore a

6. Moving a summing point before a block.

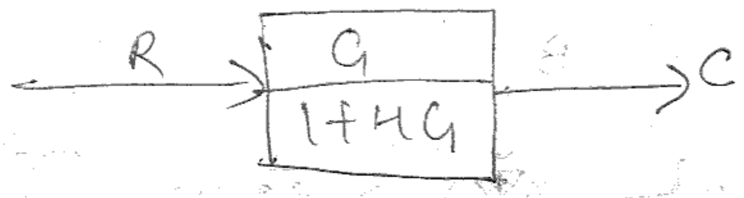




7. Eliminating the feedback path.

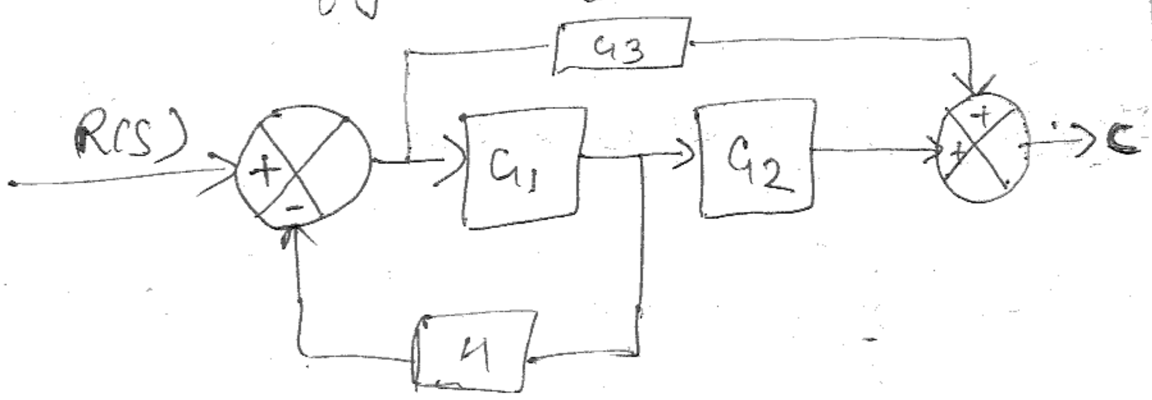


$$C = (R - CH)G$$
$$= RG - CHG$$
$$C + CHG = RG$$
$$C(1 + HG) = RG$$
$$C = \frac{RG}{1+HG}$$
$$\frac{C}{R} = \frac{G}{1+HG}$$

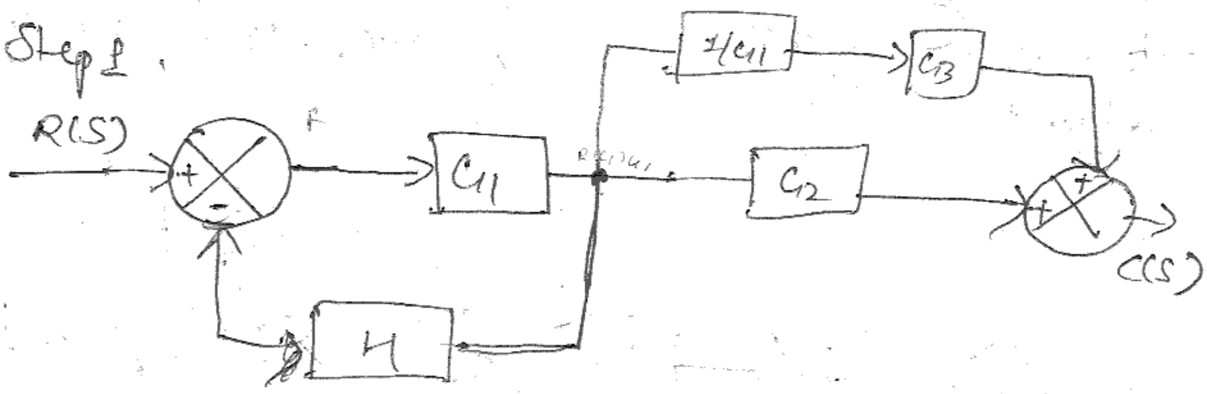


<u>Reduction</u>

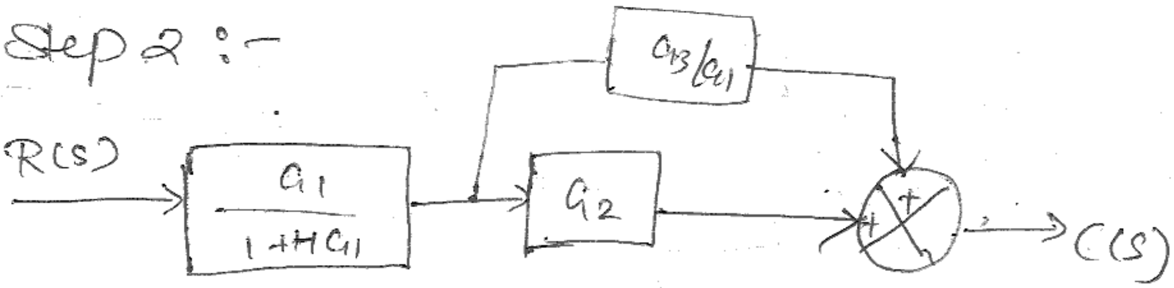
Reduce the block diagram, shown in the fig and find C(S)/R(S)

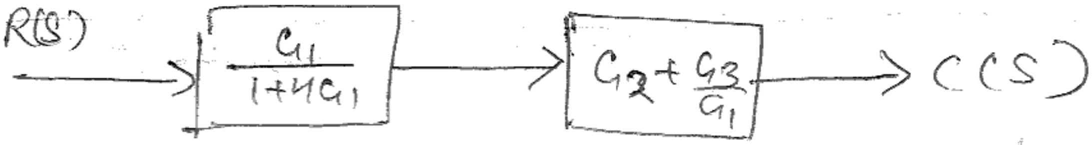


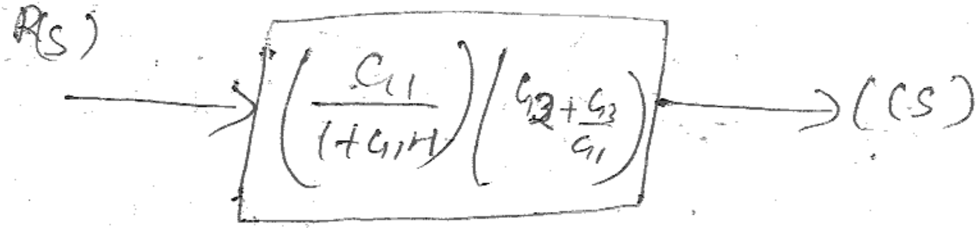
Step 1.



Step 2 :-

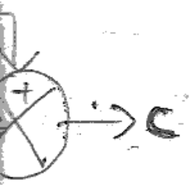






, shown

R(S)



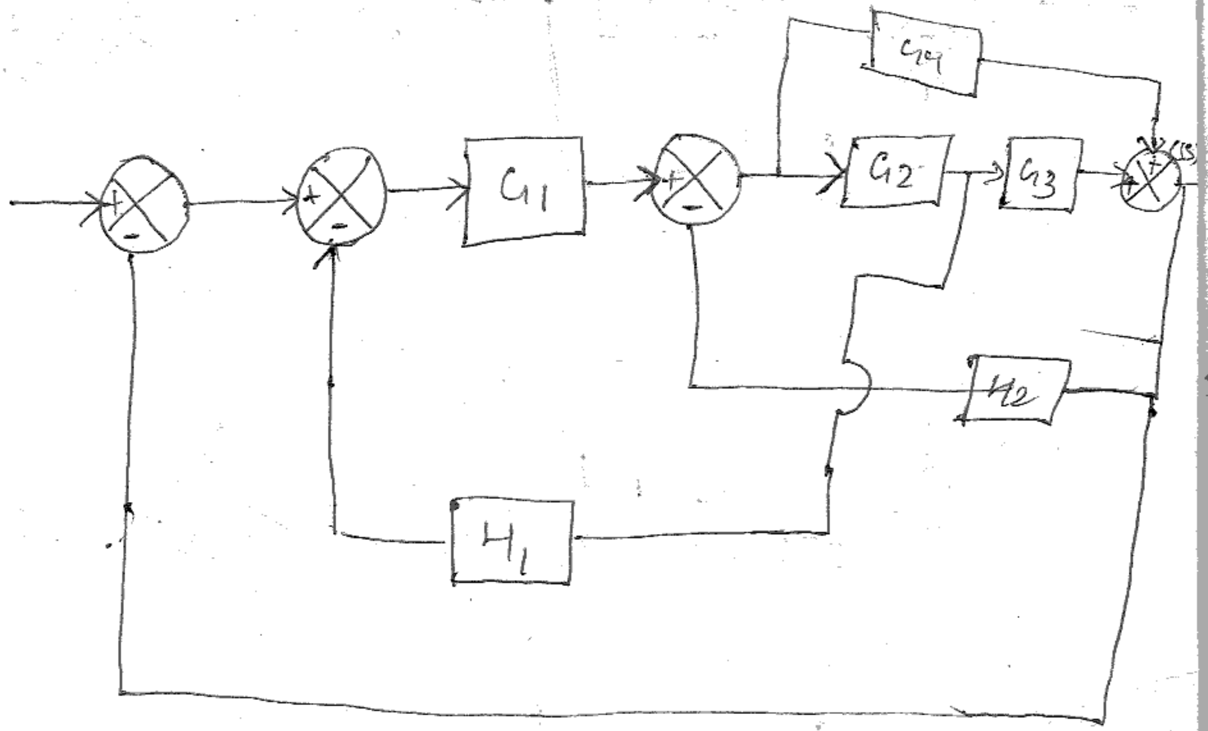
$$\frac{C(s)}{R(s)} = \left(\frac{G_1}{1+G_1H}\right)\left(G_2+\frac{G_3}{G_1}\right)$$

$$= \left(\frac{G_1}{1+G_1H}\right)\left(\frac{G_2G_1+G_3}{G_1}\right)$$

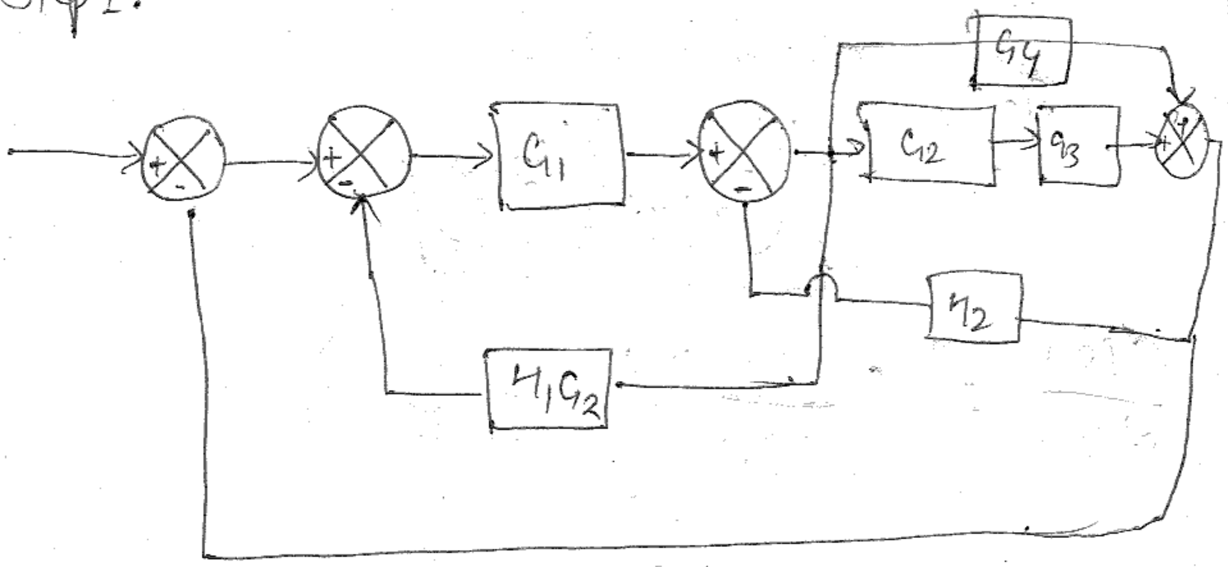
$$\boxed{\frac{C(s)}{R(s)} = \frac{G_2G_1+G_3}{1+G_1H}}$$

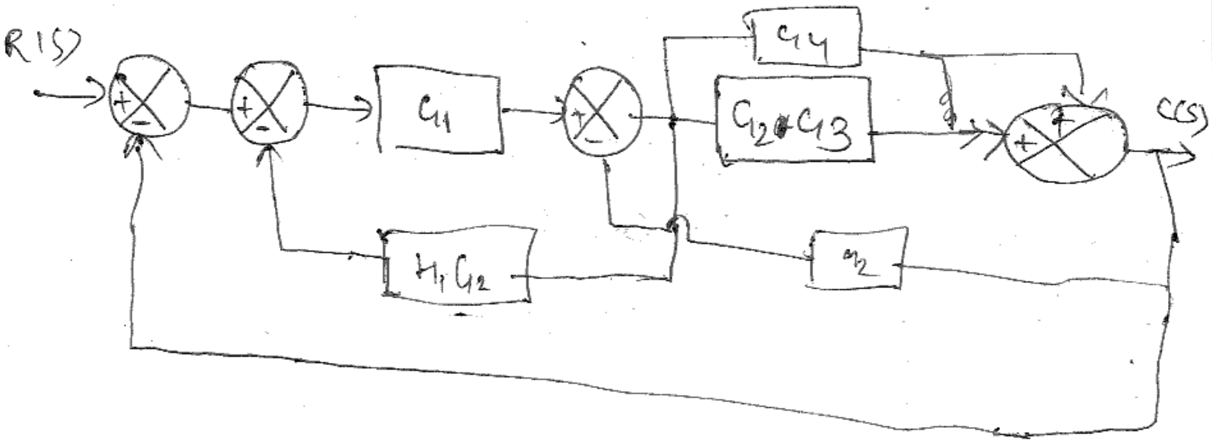
6/7/11

Q. using Block Diagram technique find the transfer function of system as shown in fig..



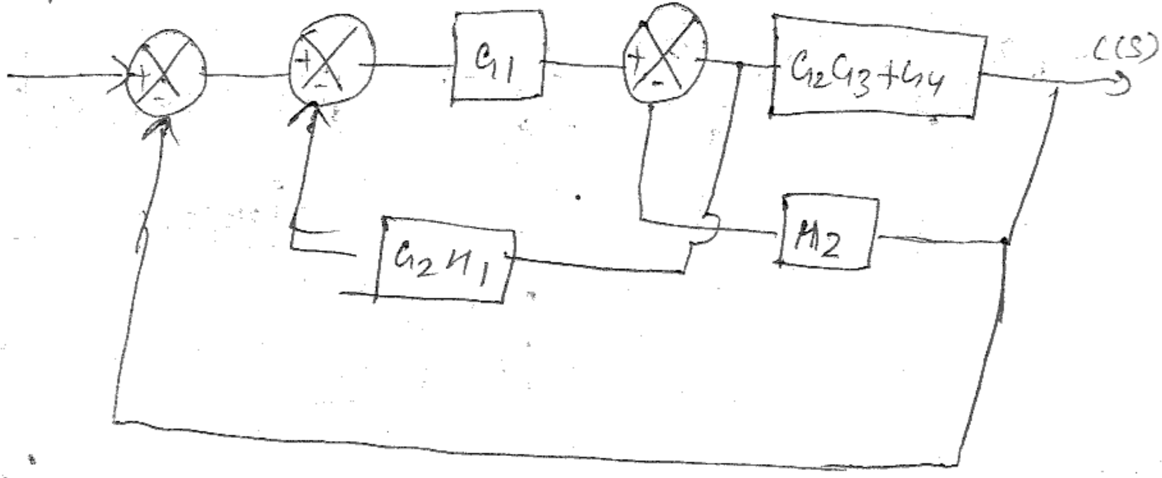
Step 1.

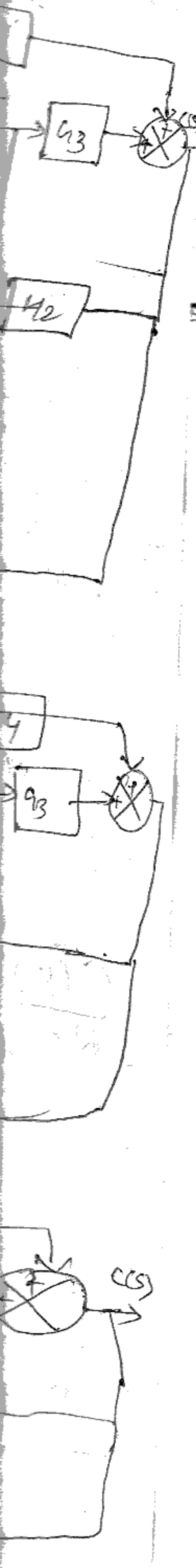




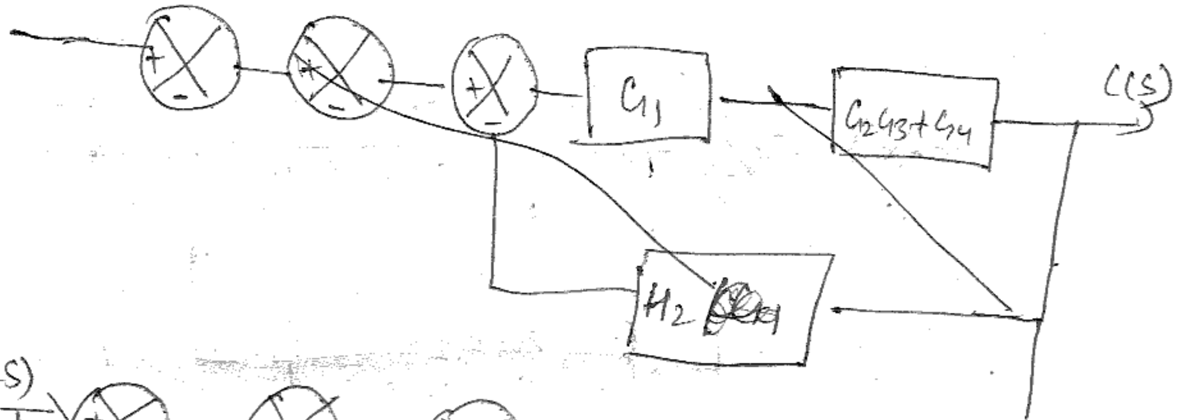
find the
shown in

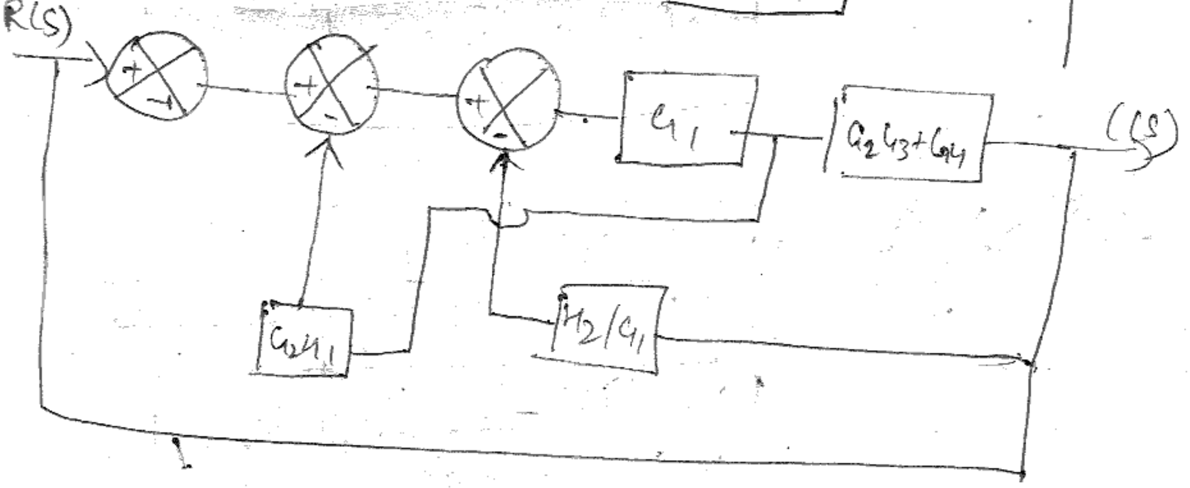
Step 2:-

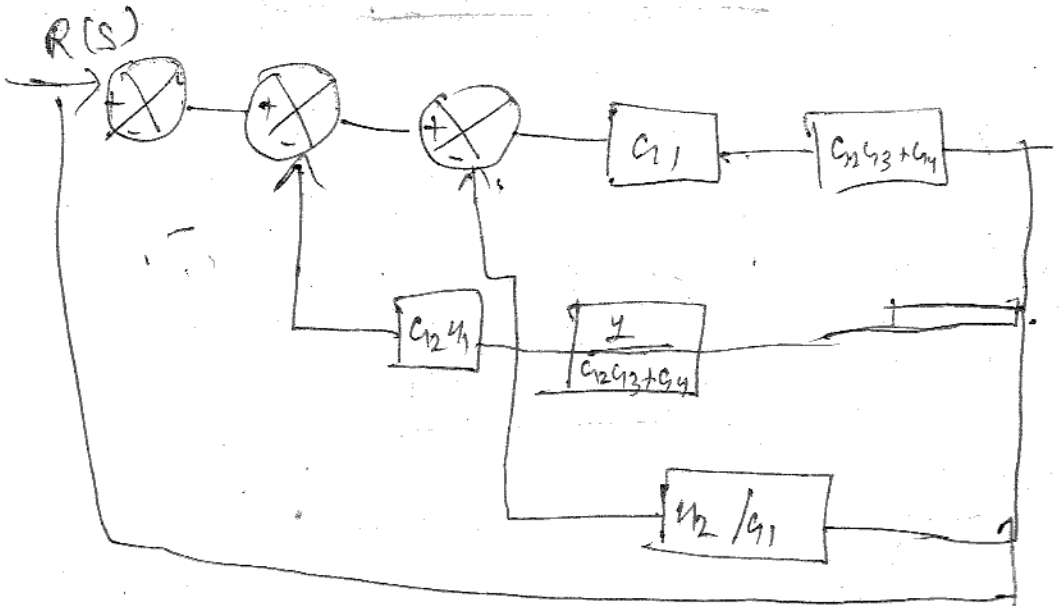


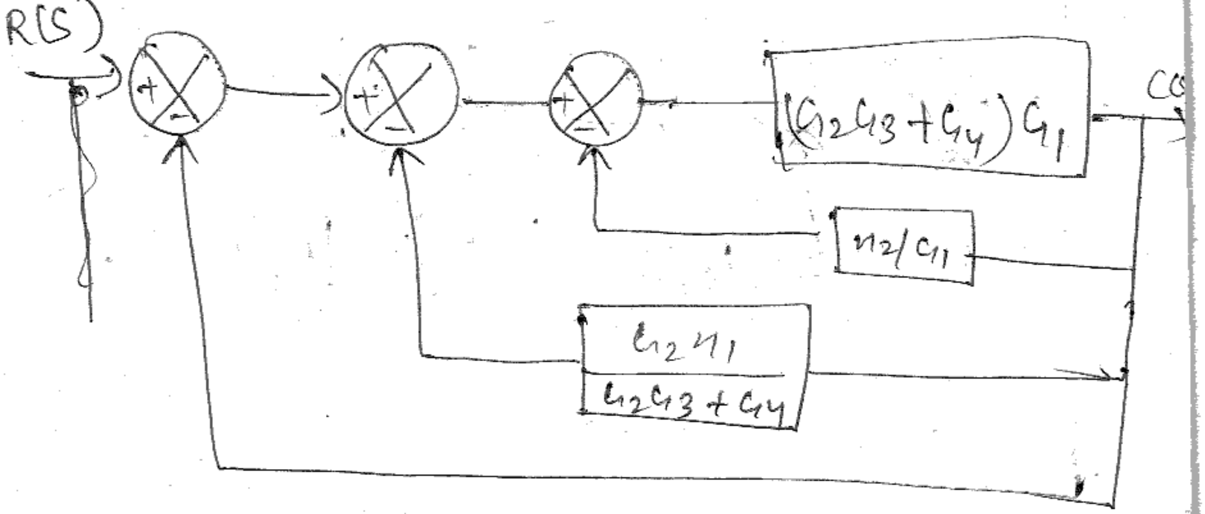


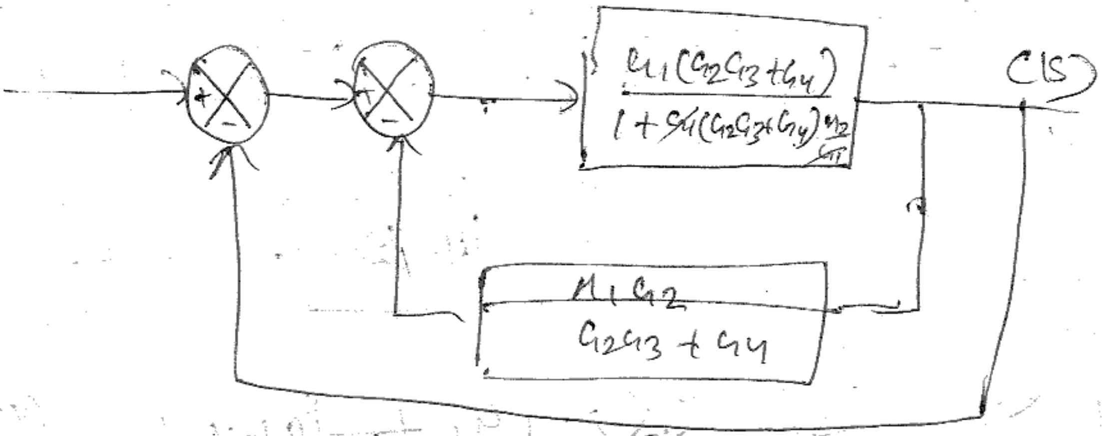
step3:

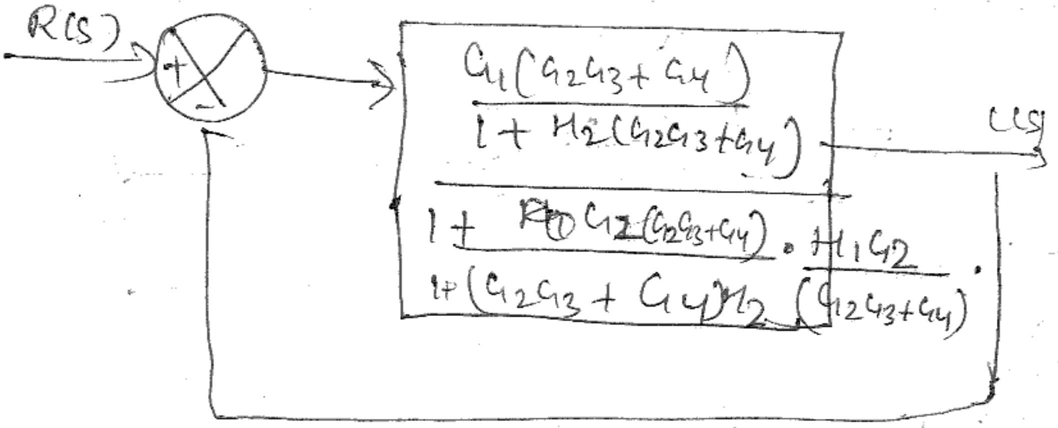


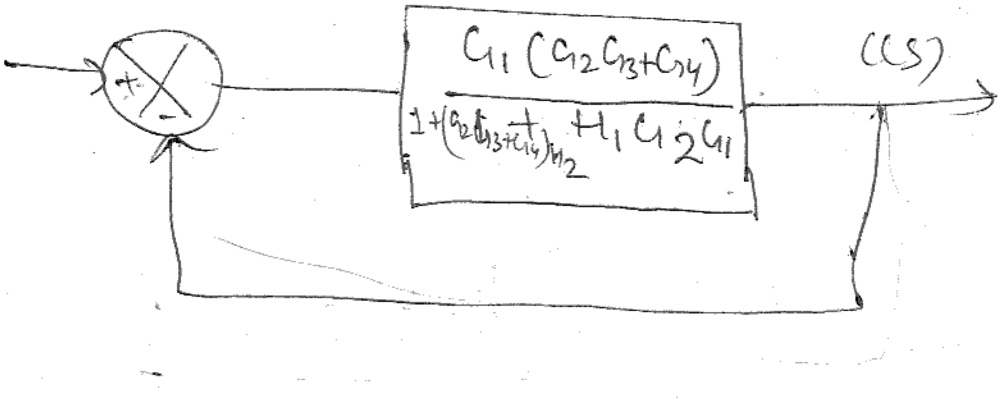


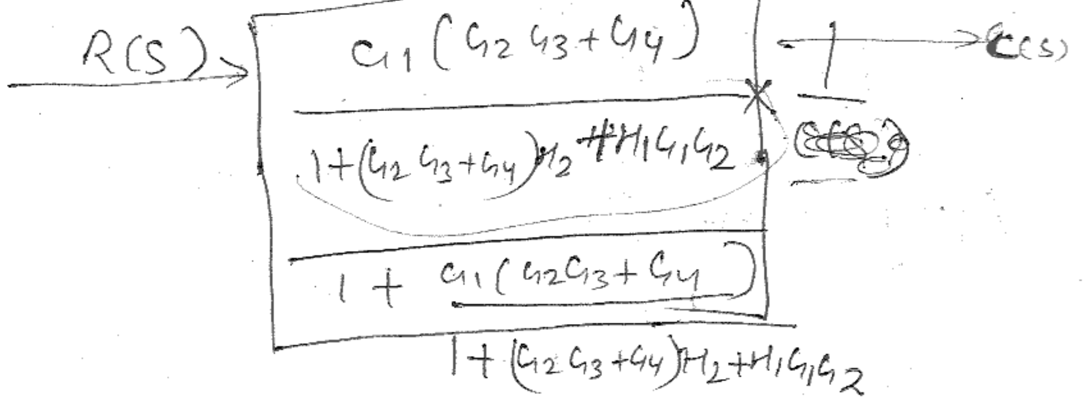


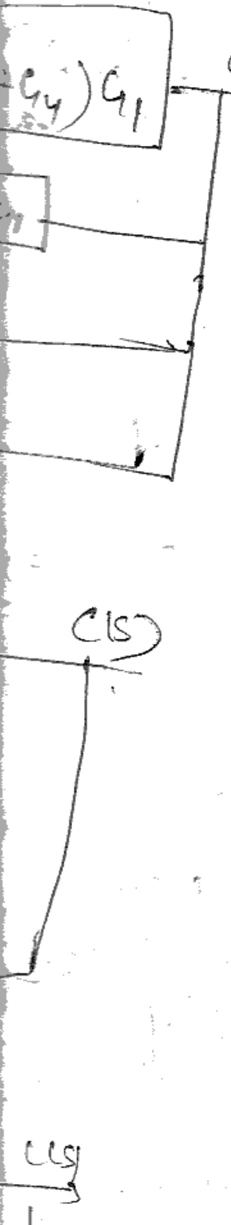

R(S)
+
-
(G2G3+G4)G1
H2/G1
G2H1 / G2G3+G4


+
-
G1(G2G3+G4) / 1+G1(G2G3+G4)H2/G1
C(S)
H1G2 / G2G3+G4


R(S)
+
-
C(S)


+
-
C(S)





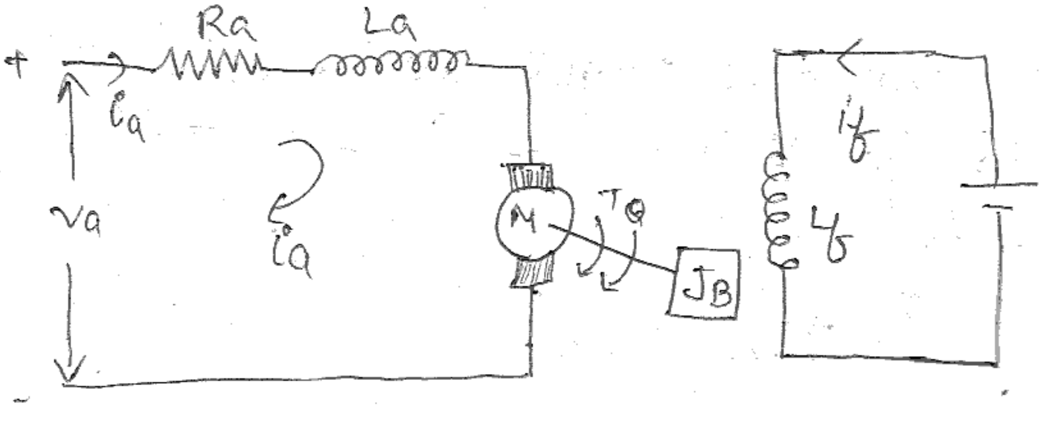
$$\frac{C(S)}{R(S)} = \frac{\dfrac{G_1(G_2G_3+G_4)}{1+\cancel{(G_2G_3+G_4)H_2+H_1G_1G_2}}}{\dfrac{1+(G_2G_3+G_4)H_2+H_1G_1G_2+G_1(G_2G_3+G_4)}{1+\cancel{(G_2G_3+G_4)+H_1G_1G_2}}}$$

$$\frac{C(S)}{R(S)} = \frac{G_1(G_2G_3+G_4)}{1+(G_2G_3+G_4)H_2+H_1G_1G_2+G_1(G_2G_3+G_4)}$$

1/7/11

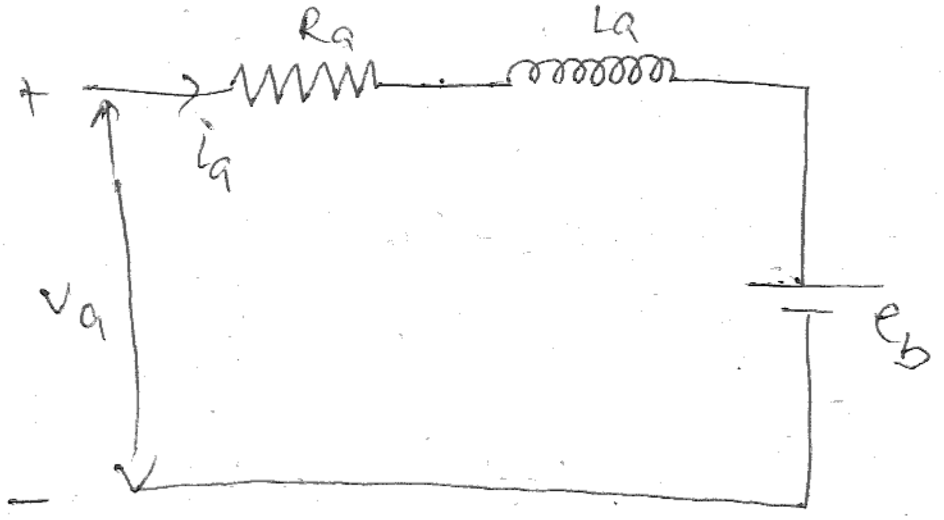
Transfer function of DC Motor

i) Armature control



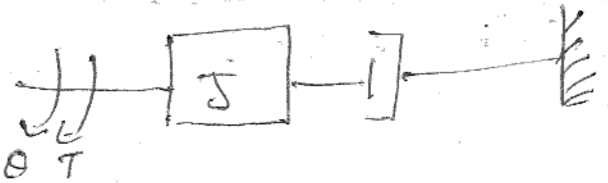
$\Rightarrow e_b \propto N$ (Speed)

Apply KVL to the Armature circuit



$$V_a = i_a R_a + L_a \frac{di_a}{dt} + e_b$$

For mechanical system



$L_f \rightarrow$ field inductance
$\theta \rightarrow$ Angular displacement

$$T_m = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} \rightarrow (2)$$

The Torque of the dc motor

In Armature control dc motor, the field Effects remains Constant. Therefore the total torque developed in the dc motor

$$T_m \propto I_a$$

$$T_m = K_t I_a$$

circuit

where $K_t \rightarrow$ Proportionality constant.

Now Equ^n (2) becomes

$$K_t I_a = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} \rightarrow (3)$$

b

Now, the back emf is directly proportional to speed (ie Angular velocity).

$$V_a = i_a R_a + L_a\frac{di_a}{dt} + K_b\frac{d\theta}{dt} \quad -(4)$$

where

$$\left\{ \begin{aligned} e_b &\propto \frac{d\theta}{dt} \\ e_b &= K_b\frac{d\theta}{dt} \end{aligned} \right\}$$

→ field inductance

→ Angular displacement

Taking the Laplace transform of equ^n (3) & equ^n (4)

$$V_a(s) = I_a(s)R_a + L_a(s)\cdot S\cdot I_a(s) + K_b S\,\theta(s)$$

r

$$K_t\cdot I_a(s) = J S^2 \theta(s) + B S\,\theta(s)$$

the

$$\theta(s) = \frac{K_t I_a(s)}{(JS^2+BS)}$$

therefore

the dc

Now

$$V_a(S) = R_a I_a(S) + L_a(s)S\, I_a(s) + K_b\cdot S\cdot\frac{K_t I_a(S)}{(JS^2+BS)}$$

$$\cancel{V_a(s) = (R_a + L_a S) I_a(s) + K_b K_t}$$

$$V_a(s) = \frac{\left[(R_a + L_a S)(JS^2 + BS) + S K_b K_t\right] I_a(s)}{(JS^2 + BS)}$$

$$I_a(s) = \frac{(JS^2 + BS)\, Q(s)}{K_t}$$

$$V_a(s) = (R_a + L_a S) I_a(s) + K_b S \theta(s)$$

$$V_a(s) = (R_a + L_a(s) S) \frac{JS^2 + BS}{K_t} Q(s) + K_b S Q(s)$$

$$V_a(s) = \frac{\left[(R_a + L_a(s) S)(JS^2 + BS) + K_b K_t S\right] \theta(s)}{K_t}$$

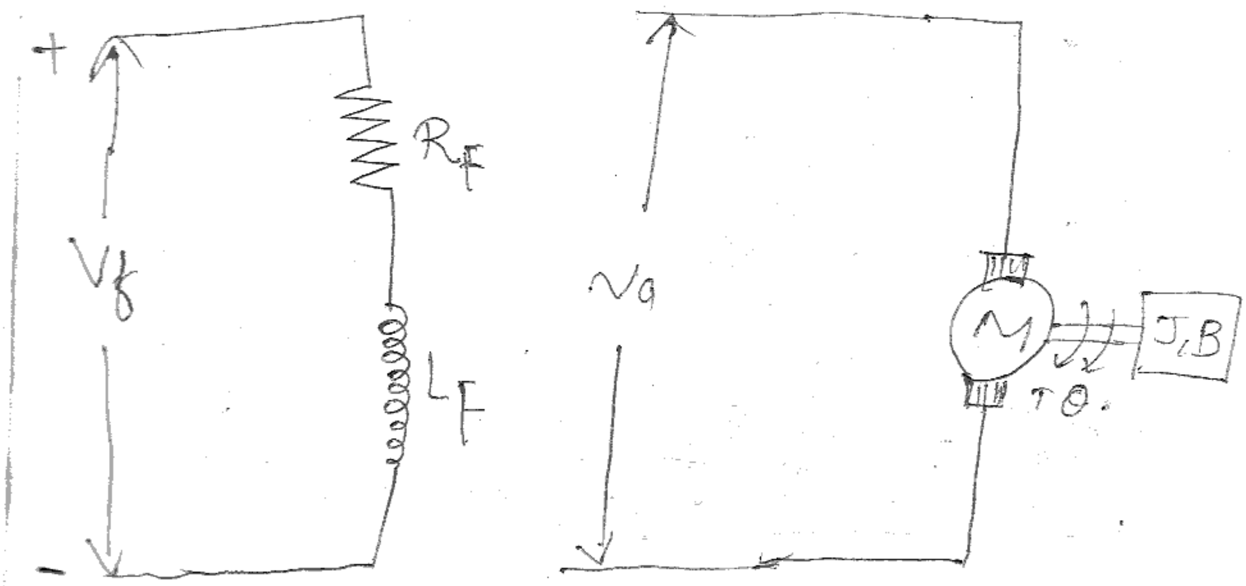
$$\frac{Q(s)}{V_a(s)} = \frac{K_t}{\left[(R_a + L_a S)(JS^2 + BS) + K_b K_t S\right]}$$

$$= \frac{K_t}{\left[R_a \left(1 + \frac{L_a S}{R_a}\right) BS \left(1 + \frac{JS^2}{BS}\right) + K_b K_t S\right]}$$

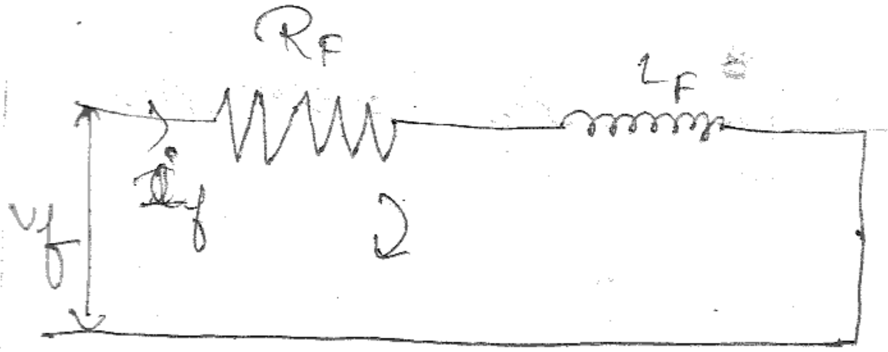
$$\frac{Q(s)}{V_a(s)} = \frac{K_t}{R_a BS \left[(1 + S T_a)(1 + T_m S) + \frac{K_b K_t}{R_a B}\right]}$$

$$\frac{L_a}{R_a} = T_a \quad , \quad \frac{J}{B} = T_m$$

Transfer function of field control-DC-Motor



Equivalent circuit of field winding



Apply KVL

$$R_f I_f + L_F \frac{di_F}{dt} = V_f$$

The torque developed in the motor T_m is directly proportional to field flux and armature current. Since the armature current is constant in this system.

The Torque is proportional to field flux

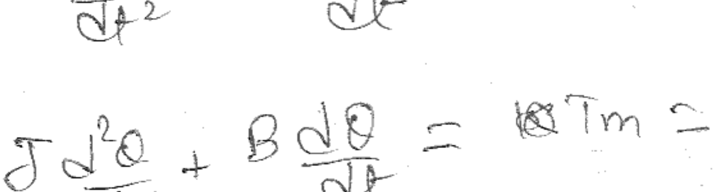
$$T_m \propto \phi_f$$

But $\phi_f \propto I_f$

$$\therefore T_m \propto I_f$$

$$\boxed{T_m = K_t I_f}$$

The mechanical system of the motor is having some differential equation, of governing mechanical system.



Mech. System.

$$J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} = T_m$$

$$J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} = T_m = K_t I_f \quad \text{—(1)}$$

motor
to field
Since the
in this
field

$$R_f I_f + L_f \frac{di_f}{dt} = V_f \rightarrow (2)$$

Taking Laplace transform for eqn (1) & (2)

$$JS^2 \theta(S) + BS\theta(S) = K_t I_f(S)$$

$$(JS^2 + BS)\,\theta(S) = K_t I_f(S)$$

$$(R_f + L_f S)\, I_f(S) = V_f(S)$$

$$\frac{(R_f + L_f S)\,(JS^2 + BS)\,\theta(S)}{K_t} = V_f(S)$$

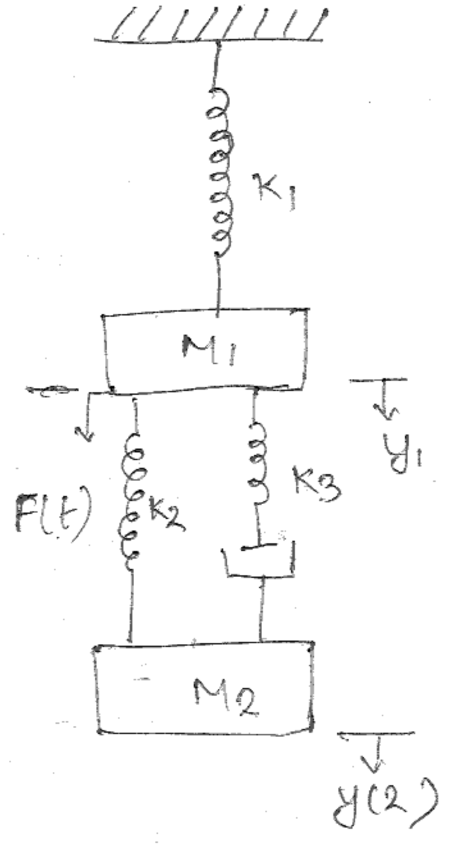
$$\frac{\theta(S)}{V_f(S)} = \frac{K_t}{(R_f + L_f S)(JS^2 + BS)}$$

for ub
of

Assignment

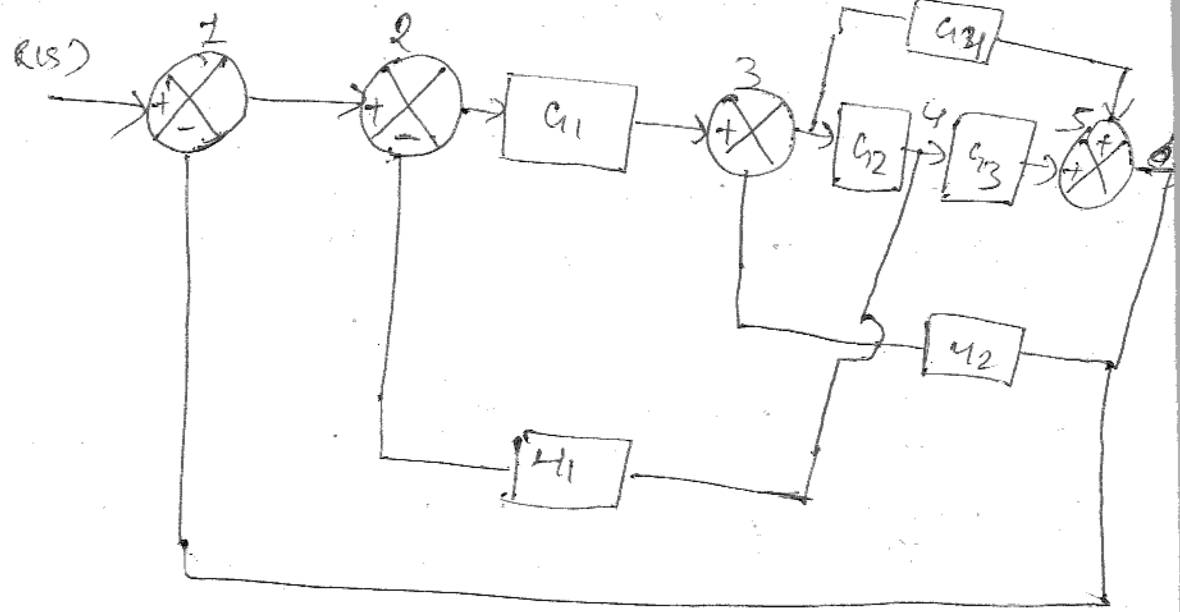
Q. Determine the Transfer function of $\frac{Y_2(S)}{F(S)}$

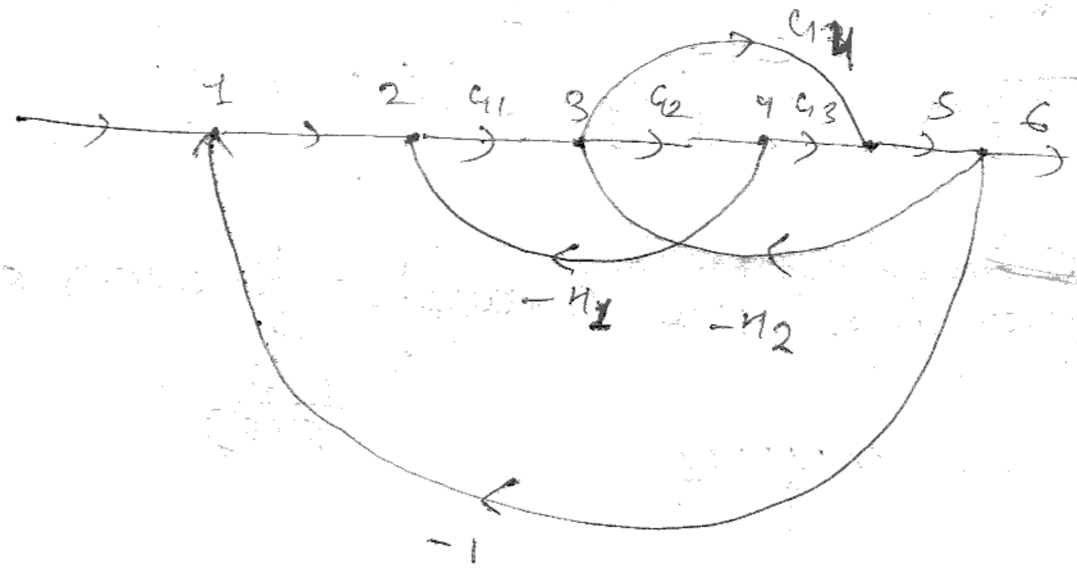
System.



(1)

Q2. Convert the block Diagram into Signal flow graph and determine the Transfer function.





Q3. Determine the Transfer function