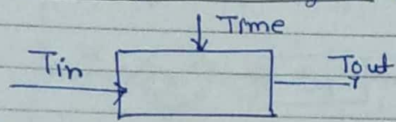
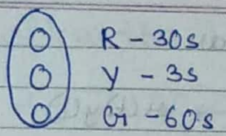
Control System

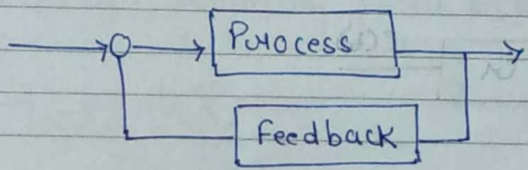
→ Open loop Control system:





→ Close loop Control System:

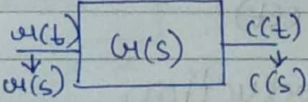
Eg - when traffic police Conducts traffic.



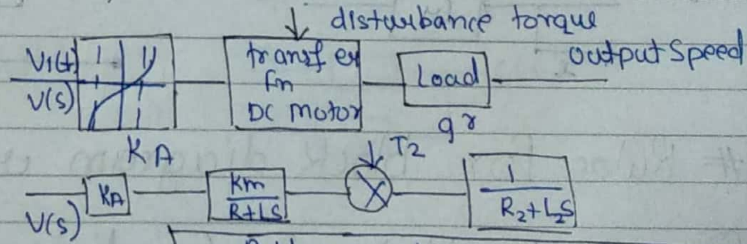
Q Difference b/w open loop Control System and close loop Control System?

DC Motor

Non-linear = Outer , linear = Inner



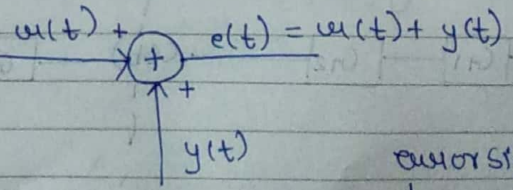
$\frac{C(s)}{R(s)} = G(s)$

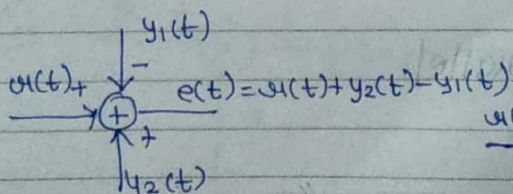


• All are linear

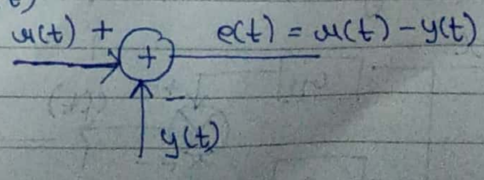
#

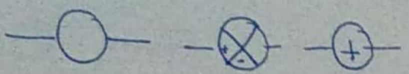
① Summing point





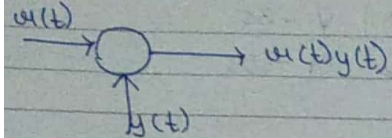
error signal





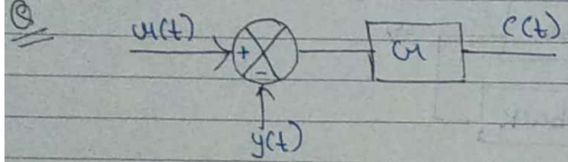
Summing point

→ Non-linear



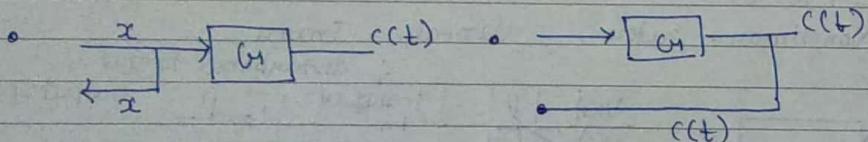
→ take its laplace using Convolution.

Q



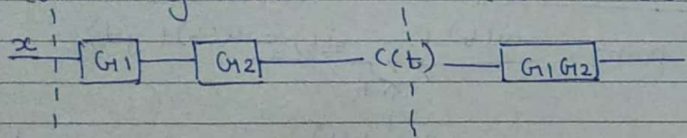
$\Rightarrow C(s) = (R(s) - Y(s))G(s)$

② Take of point

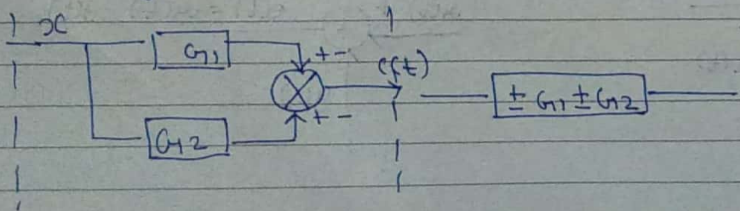


Rules for block diagram reduction

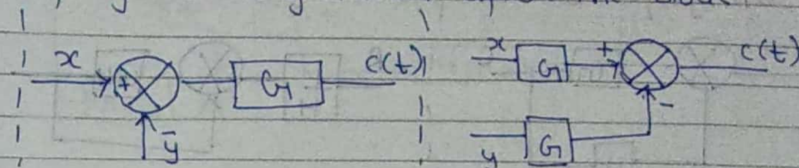
① Combining blocks in Cascade or Series



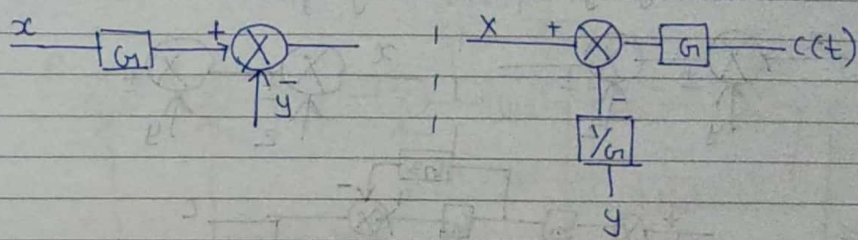
② Combining blocks in parallel



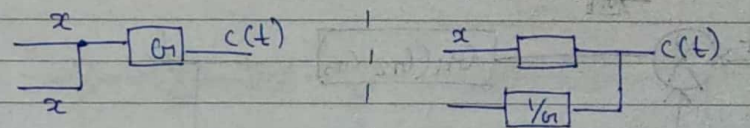
③ Shifting Summing element after the block



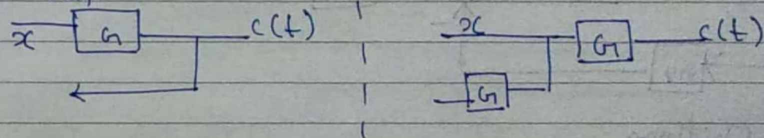
④ Shifting Summing point before the block



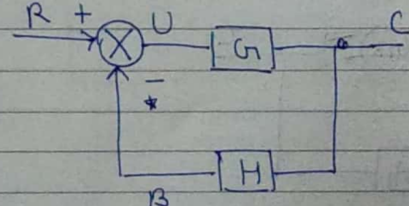
⑤ Shifting take of point after the block



Ⓒ before.



Q



$B = CH$

$U = R - CH$

$C = (R - CH)G$

$\frac{C}{R} = \frac{G}{1 + GH}$ — G: forward path gain; GH → feedback path gain

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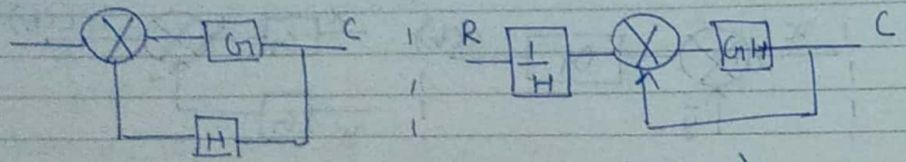
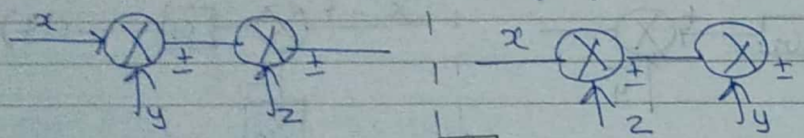
Date : / /

7) Unity feedback

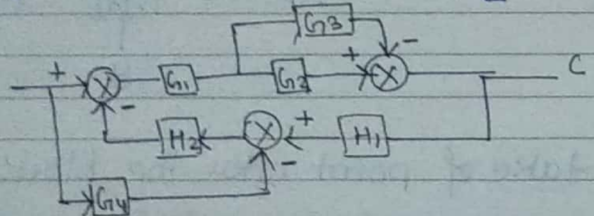


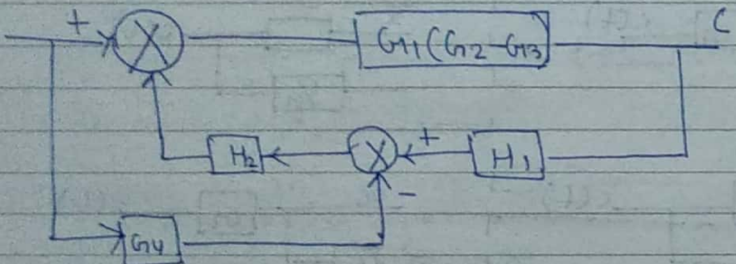
$$\left(\frac{GH}{1+GH}\right)$$

8) Interchanging of Summing point.

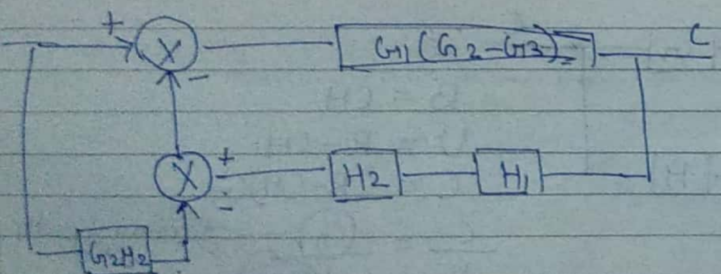


Q





→ Shifting.



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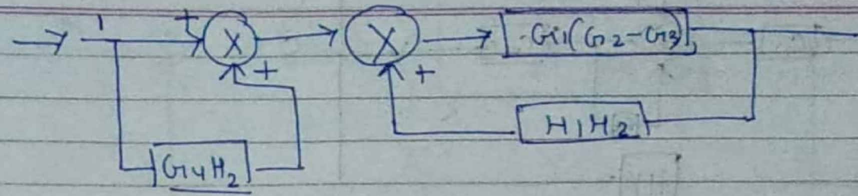
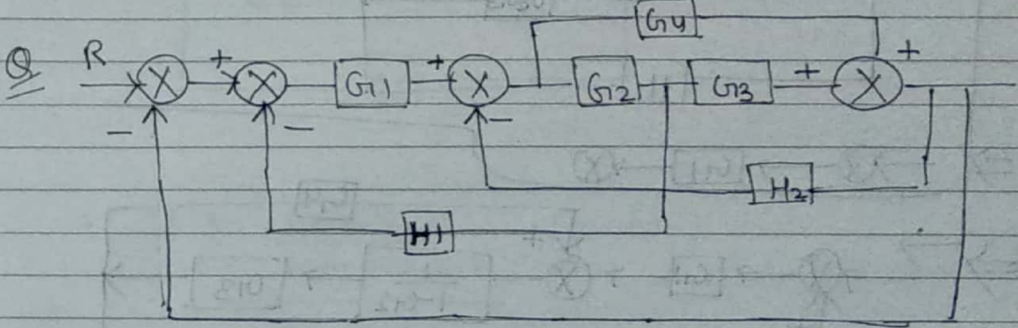
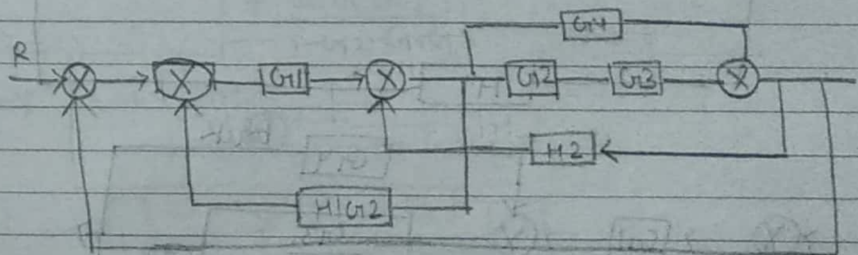
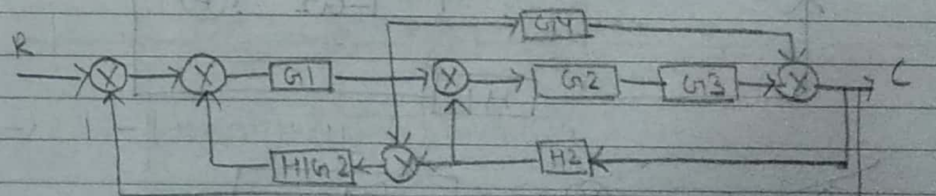


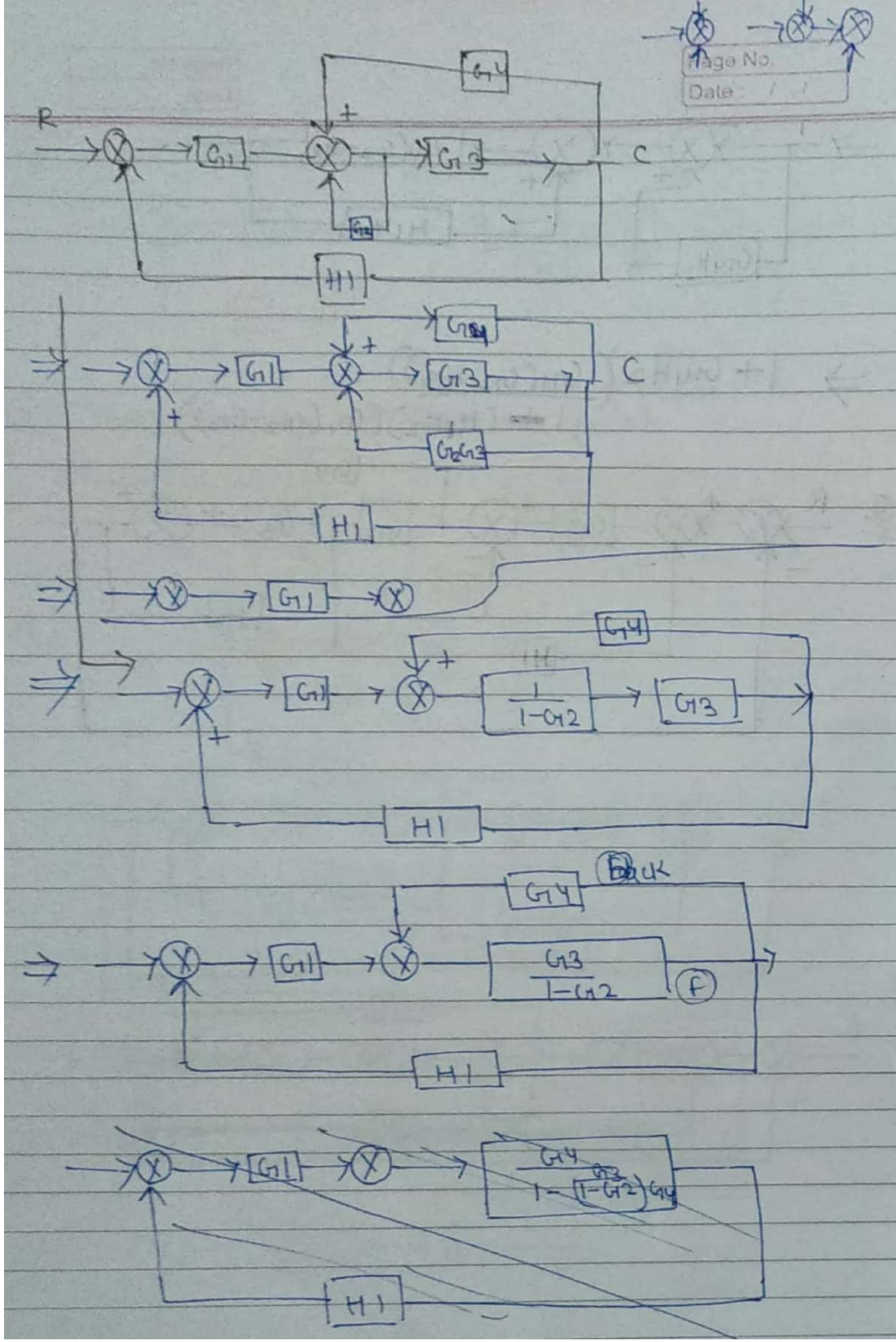
$$\Rightarrow \quad 1 + G_4H_2\left(\frac{G_1(G_2-G_3)}{1 - (H_1H_2)(G_1(G_2-G_3))}\right)$$

Q

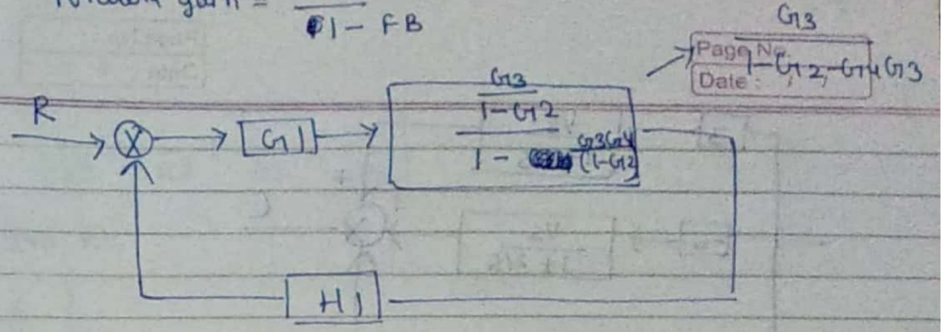




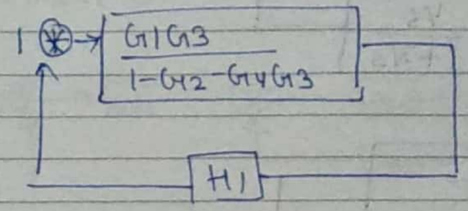




forward gain = $\frac{F}{1-FB}$



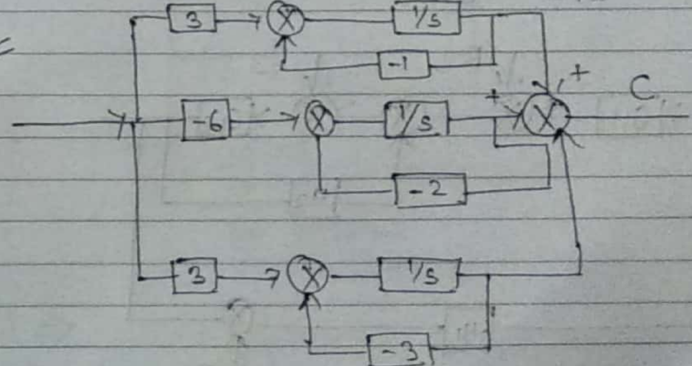
$\Rightarrow$

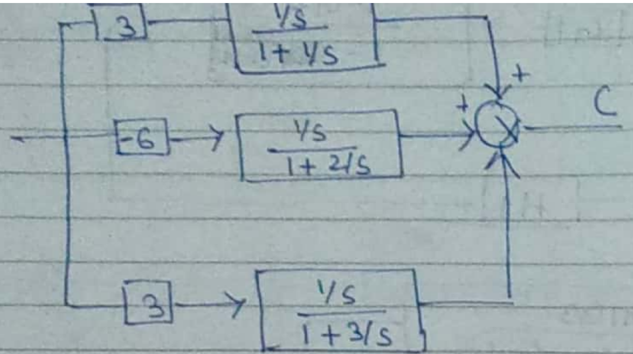


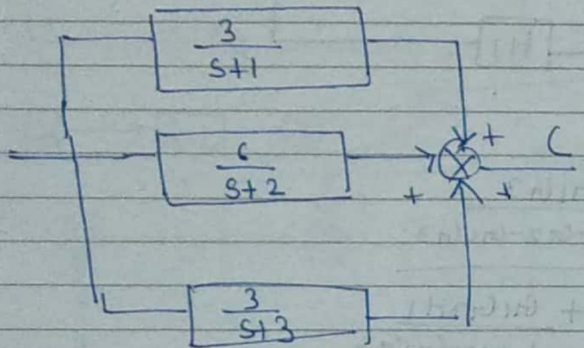
$$= \frac{1 + \frac{G_1G_3}{1-G_2-G_4G_3}}{1 + \frac{G_1G_3H_1}{1-G_2-G_4G_3}}$$

$$\Rightarrow 1 + \frac{G_1G_3}{1-G_2-G_4G_3+G_1G_3H_1}$$

Q.

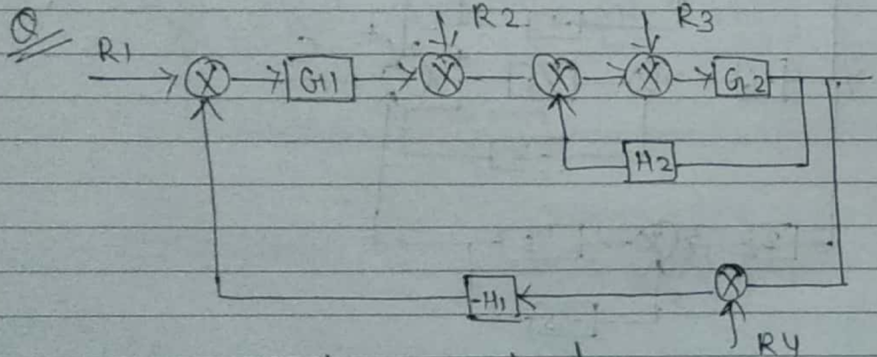






$$\frac{3}{s+1} - \frac{6}{s+2} + \frac{3}{s+3}$$

Q



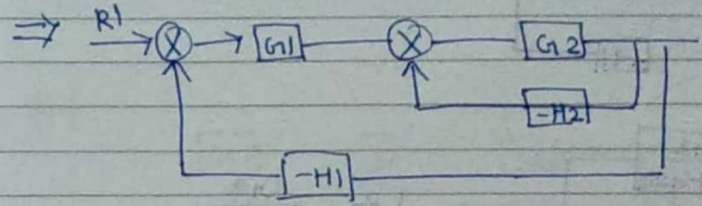
→ Many input one output

$$\boxed{\frac{C}{R1} + \frac{C}{R2} + \frac{C}{R3} + \frac{C}{R4}}$$

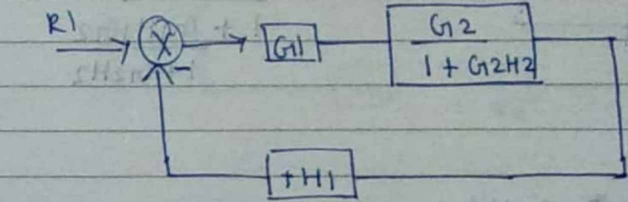
find R1,

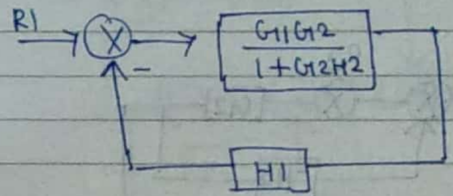
$$\left.\frac{C}{R1}\right|_{R2,R3,R4=0}$$

⇒



=



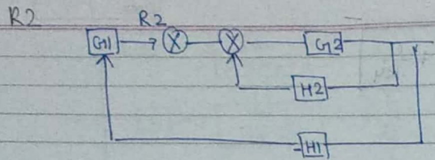


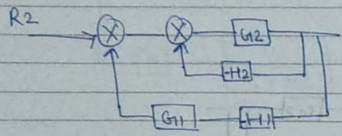
$$= 1 + \frac{\frac{G_1G_2}{1+G_2H_2}}{1 + \frac{H_1G_1G_2}{1+G_2H_2}}$$

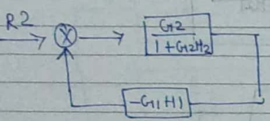
R1 ⇒

$$\Rightarrow 1 + \frac{G_1G_2}{1+G_2H_2+H_1G_1G_2}$$

Scanned by CamScanner

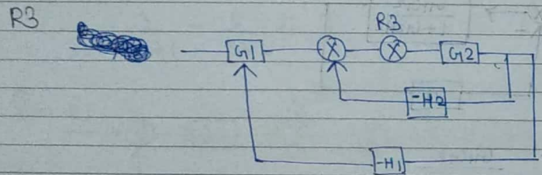


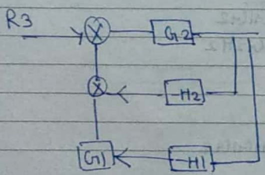


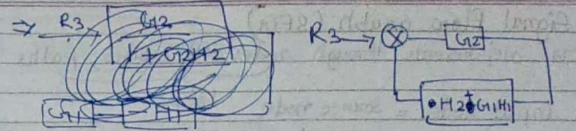


$$\Rightarrow 1 + \frac{\frac{G_2}{1+G_2H_2}}{1+\frac{G_1H_1G_2}{1+G_2H_2}}$$

$$\Rightarrow 1 + \frac{G_2}{1+G_2H_2+G_1H_1G_2}$$

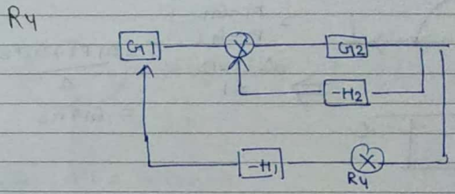


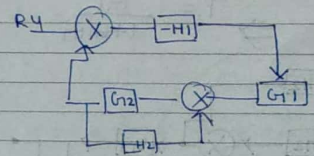




$$= \frac{G_2}{1+(H_2+G_1H_1)G_2}$$

R4





$$\Rightarrow \frac{-H_1G_1G_2}{1+H_2G_2+H_1G_1G_2}$$

Q-12

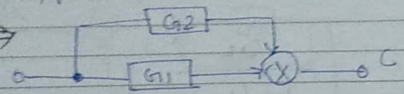
Signal flow graph (SFG)

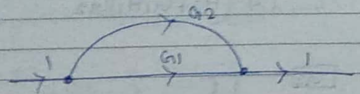
It represents through nodes and arrow, paths
loops

input node = Source node

o/p node = Sink node

⇒





$P1 = G1$

$P2 = G2$

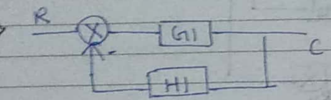
$\Delta = 1-0$

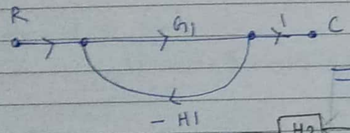
$= 1$

$$T = \frac{\Delta_1 P1 + \Delta_2 P2}{\Delta}$$

$= G1 + G2$

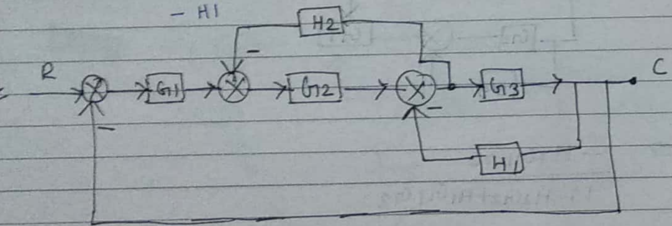
⇒

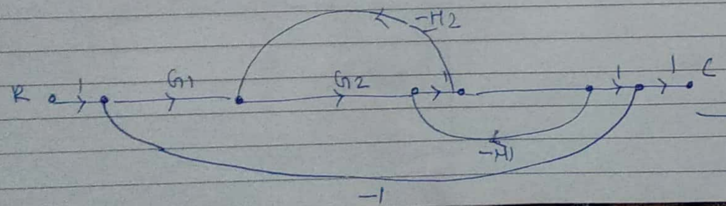




⇒ $T = \dfrac{G1}{1+G1H1}$

Q



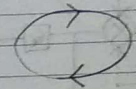


Mason gain

$$= \frac{P1\Delta_1 + P_2\Delta_2 + \dots + P_n\Delta_n}{\Delta}$$

P1, P2, P3 — Pk = forward path

Δ = 1 − (single loop) + (two non touching loops) − (three non touching loop)



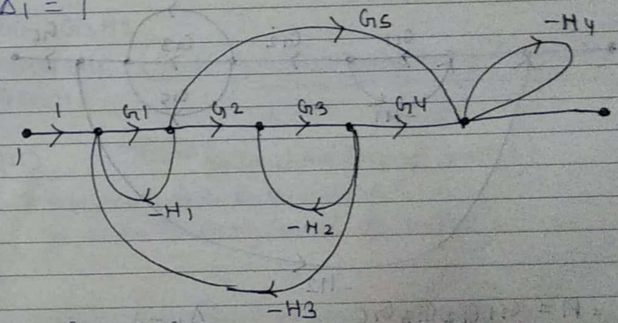
→ Single loop

$P1 = G_1G_2G_3$

$\Delta = 1-(-G_2H_2 - G_3H_1 - G_1G_2G_3)$

$\Delta_1 = 1$

Q



$P1 = G_1G_2G_3G_4$

$P2 = G_1G_5$

$S1 = -G_1H_1$

$S2 = -G_3H_2$

$S3 = -H_4$

$S_4 = -G_1G_2G_3H_4$

$2nT = 4$

$3nT = -G_1H_1G_3H_2H_4$

Δ

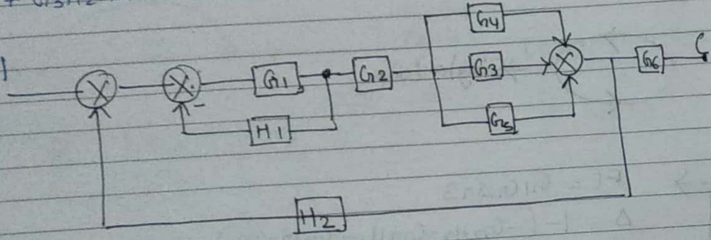
$\Delta_1 = 1$

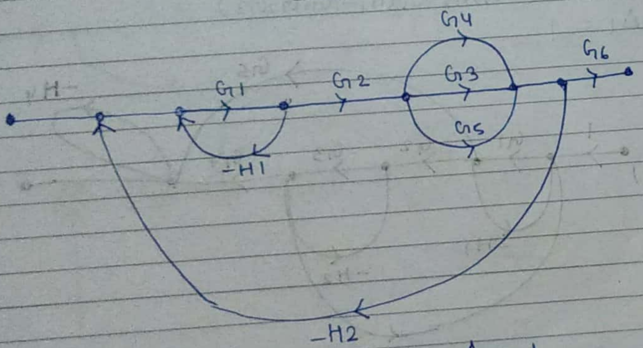
$\Delta_2 = 1 - (-G_3H_2)$

$= 1 + G_3H_2$

$$\Rightarrow \frac{G_1G_2G_3G_4 + G_1G_5(1+G_3H_2)}{1 + G_1H_1 + G_3H_2 + H_4 + G_1G_2G_3H_3 + G_1H_1G_3H_2 + G_1H_1H_4 + G_3H_2H_4 + G_1G_2G_3H_3H_4 + G_1H_1G_3H_2H_4}$$

Q-1





Solve = $P_1 = G_1G_2G_3G_6$ $\Delta_1 = 1$

$P_2 = G_1G_2G_4G_6$ $\Delta_2 = 1$

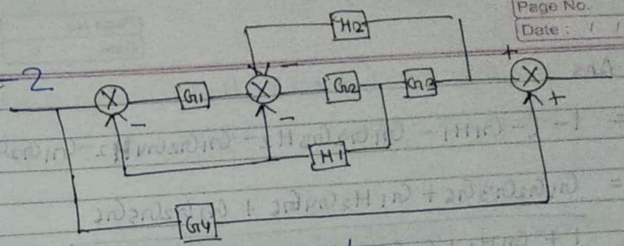
$P_3 = G_1G_2G_5G_6$ $\Delta_3 = 1$

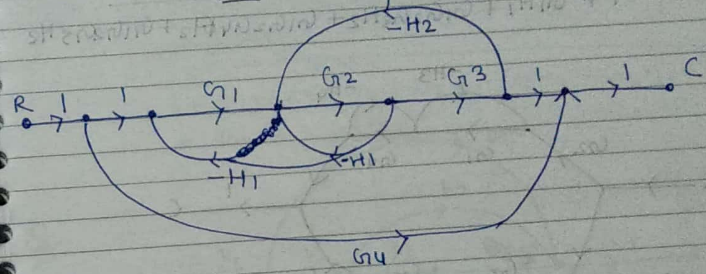
$S_1 = -G_1G_2G_3H_2$

$S_2 = -G_1H_1$

$S_3 = -G_1G_2G_4H_2$ $S_4 = -G_1G_2G_5H_2$

Q-2





1 → $P_1 = G_1G_2G_3$ $SL = 3$, $DL = 0$

$P_2 = G_4$. $\Delta_2 \neq 2$

$\Delta_2 = 1$

2 $SL_1 = \rightarrow G_2G_3H_2$

$SL_2 = \rightarrow G_1G_2H_1$

$SL_3 = \rightarrow G_2H_1$

3 $\Delta = 1 - (-G_2G_3H_2 - G_1G_2H_1 - G_2H_1) + 0 - 0$

4 $\Delta_1 = 1 + 0$ (Non-Touching loop of path 1)

5 $\Delta_2 = 1 + G_2G_3H_2 + G_1G_2H_1 + G_2H_1$ (1 + Non-Touching loop of of path 2)

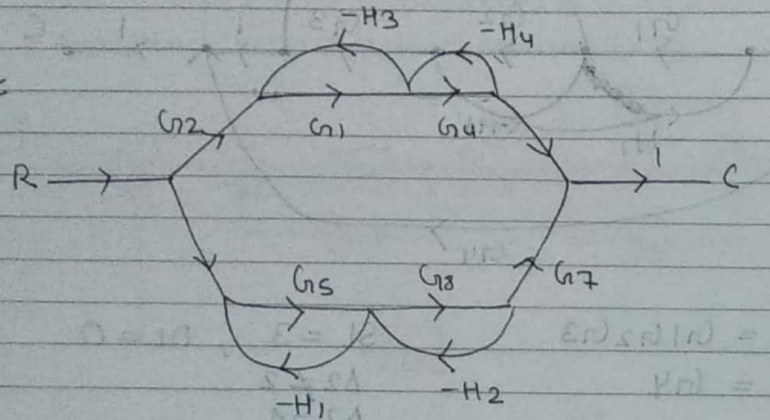
6 $$\Rightarrow T = \frac{G_1G_2G_3 \times 1 + G_4(1 + G_2G_3H_2 + G_1G_2H_1 + G_2H_1)}{1 + G_2G_3H_2 + G_1G_2H_1 + G_2H_2}$$

Q-1 Ans

$$\Delta = 1-(-G_1H_1 - G_1G_2G_3H_2 - G_1G_2G_4H_2 - G_1G_2G_5H_2)$$

$$M.G = \frac{G_1G_2G_3G_6 + G_1H_2G_4G_6 + G_1G_2G_5G_6}{1 + G_1H_1 + G_1G_2G_3H_2 + G_1G_2G_4H_2 + G_1G_2G_5H_2}$$

Q



Path

$P1 = G_2G_1G_4$

$P2 = G_2G_5G_8G_7$

$$\Delta = 1-(-G_1H_3 - G_4H_4 - G_5H_1 - G_8H_2) + (-G_5H_1 - G_8H_2) + (-G_1H_3 - G_4H_4)$$

Self loop.

$SL1 = -G_1H_3$

$SL2 = -G_4H_4$

$SL3 = -G_5H_1$

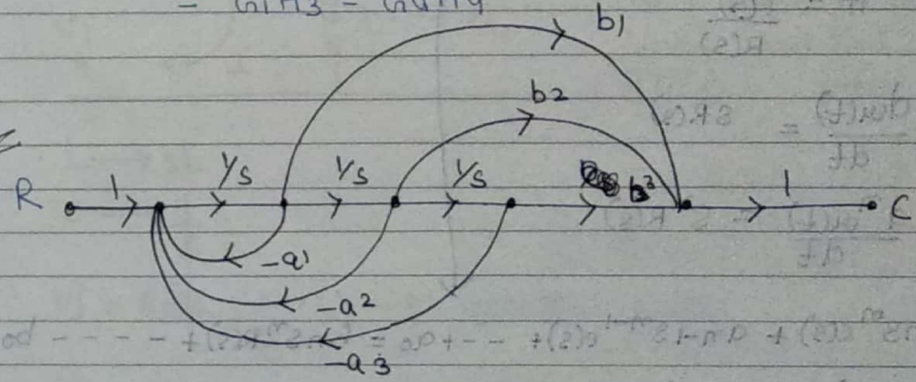
$SL4 = -G_8H_2$

$$\Delta_1 = 1-(-G_5H_1 - G_8H_2) \Rightarrow 1 + G_5H_1 + G_8H_2$$

$$\Delta_2 = 1-(-G_1H_3 - G_4H_4) \Rightarrow 1 + G_1H_3 + G_4H_4$$

$$\Rightarrow T = \frac{G_2G_1G_4(1 + G_5H_1 + G_8H_2) + G_2G_5G_8G_7(1 + G_1H_3 + G_4H_4)}{1 + G_1H_3 + G_4H_4 + G_5H_1 + G_8H_2 - G_5H_1 - G_8H_2 - G_1H_3 - G_4H_4}$$

Q



⇒ Path

$P1 = \frac{b^3}{s^3}$

$P2 = \frac{b1}{s}$

$P3 = \frac{b^2}{s^2}$

$SL1 = -\frac{a^1}{s}$

$SL2 = -\frac{a^2}{s^2}$

$SL3 = -\frac{a^3}{s^3}$

NTL = 0.

$\Delta 1 = 1$

$\Delta 2 = 1$

$\Delta 3 = 1$

$$T = \frac{\frac{b^3}{s^3} + \frac{b^1}{s} + \frac{b^2}{s^2}}{1 + \frac{a^1}{s} + \frac{a^2}{s^2} + \frac{a^3}{s^3}}$$

CL more stable than OL

initially Value must be 0, initial state (0)

R(s) → [G(s)] → C(s)

r(t) → c(t)

$$\Rightarrow a_n \frac{d^n c(t)}{dt^n} + a_{n-1}\frac{d^{n-1}c(t)}{dt^{n-1}} + \cdots a_1\frac{dc(t)}{dt} + a_0 = b_n\frac{d^n}{dt^n}r(t)$$

$$+ b_{n-1}\frac{d^{n-1}}{dt^{n-1}}r(t) + \cdots b_0.$$

$$\rightarrow TF = \frac{C(s)}{R(s)}$$

$$\frac{dr(t)}{dt} = sR(s)$$

$$\frac{d^n r(t)}{dt} = s^n R(s)$$

$$\Rightarrow a_n s^n C(s) + a_{n-1}s^{n-1}C(s) + \cdots + a_0 = b_n s^n R(s) + \cdots b_0$$

$$\Rightarrow \frac{C(s)}{R(s)} = \frac{a_n s^n \cdots a_0}{b_n s^n \cdots b_0}$$

Q $\frac{dy(t)}{dt} + 4y(t) = \frac{dx(t)}{dt} + 5x(t)$ find the transfer function, o/p = y(t) and i/p = x(t)

Solve $sY(s) + 4y(s) + sX(s) + 5X(s)$

$$\boxed{\frac{Y(s)}{X(s)} = \frac{s+5}{s+4}}$$

poles = T.F tends to change ∞

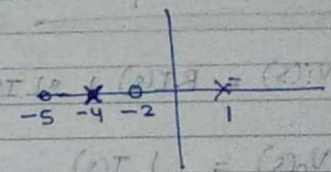
zero = " 0

if $\frac{y(s)}{X(s)} = \frac{(s+5)(s+2)}{(s+4)(s-1)}$

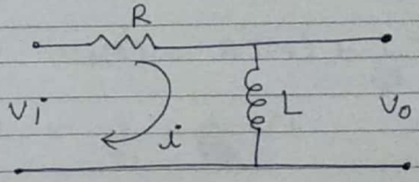
then find poles and zero.

= zeros → −5, −2

poles → −4, 1



Q



Find transfer function $\frac{V_o(s)}{V_i(s)}$ and find zero, poles.

$L \rightarrow sL$

$C \rightarrow \frac{1}{s}$

$V_i = Ri(t) + L\frac{di(t)}{dt}$ — ①

$V_o = L\frac{di(t)}{dt}$ — ②

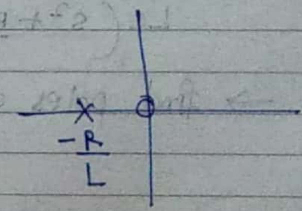
① Laplace

$V_i(s) = RI(s) + LsI(s)$

② $V_o(s) = sLI(s)$

$$\frac{V_o(s)}{V_i(s)} = \frac{sL}{sL+R}$$

$$\Rightarrow \frac{s}{s+\frac{R}{L}}$$



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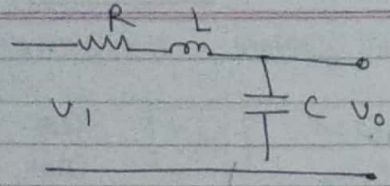


$$V_i(s) = R I(s) + sL I(s) + \frac{1}{Cs} I(s)$$

$$V_0(s) = \frac{1}{Cs} I(s)$$

$$\frac{V_0(s)}{V_i(s)} = \frac{\frac{1}{Cs}}{\frac{1}{Cs} + sL + R}$$

$$\frac{V_0(s)}{V_i(s)} = \frac{1}{1 + s^2 LC + RCs}$$

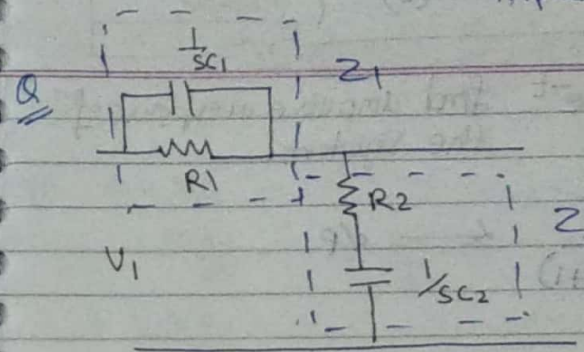
$$\frac{V_0(s)}{V_i(s)} = \frac{1}{LC\left(\frac{1}{LC} + s^2 + \frac{RCs}{LC}\right)}$$

$$= \frac{1}{LC\left(s^2 + \frac{RCs}{LC} + \frac{1}{LC}\right)}$$

→ find poles and zeroes

impulse fn → o/p $G(s) = C(s)$.
impulse response of system → means we ignore input value we just do laplace.

Q



$$\Rightarrow V_0(s) = R I(s) + \frac{1}{C_2 s} I(s)$$

$$\frac{1}{Z_1} = \frac{1}{R_1} + sC_1 \qquad \left(R_1 \parallel \frac{1}{sC_1}\right)$$

$$\frac{1}{Z_1} = \frac{1 + sC_1R_1}{R_1} \Rightarrow Z_1 = \frac{R_1}{1 + R_1 sC_1}$$

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

$$\text{T.f.} = \frac{V_0(s)}{V_i(s)} = \frac{Z_2(s)}{Z_1(s) + Z_2(s)}$$

$$= \frac{\left(\frac{R_2 sC_2 + 1}{sC_2}\right)}{\left(\frac{R_1}{1 + R_1 sC_1}\right) + \left(\frac{R_2 sC_2 + 1}{sC_2}\right)}$$

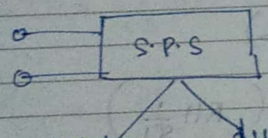
$$\Rightarrow \frac{(1 + R_1 C_1 s)(1 + R_2 C_2 s)}{}$$

$C(s) = G(s)$ when I/P $= \delta(t)$

Q $c(t) = -te^{-t} + 2e^{-t}$ find impulse response of the System.
$r(t) = \delta(t) \leftarrow$ I/P.

Soln $= -\frac{1}{(s+1)^2} + \frac{2}{(s+1)} \leftarrow$ O/P

→ Single port System



driving impedence

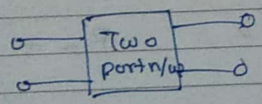
$Z = \frac{V_0}{I(s)}$

driving admittance

$Y = \frac{I_s}{V_0(s)}$

driving point function.

- Voltage TF $= \frac{V_o(s)}{V_i(s)}$
- Current TF $= \frac{I_o(s)}{I_I(s)}$

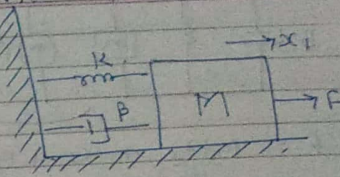


$Z_{12} = \frac{V_i(s)}{I_o(s)}\frac{\text{I/P}}{\text{O/P}}$ $Z_{21} = \frac{V_o(s)}{I_i(s)}\frac{\text{O/P}}{\text{I/P}}$

$Y_{12} =$ $Y_{21} =$

Machanical System

⇒



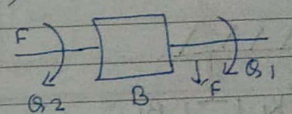
① $F = Ma$

$m\frac{dv}{dt}$, $v = \frac{dx}{dt}$

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

$F = m\frac{d^2(x_1 - x_2)}{dt^2}$

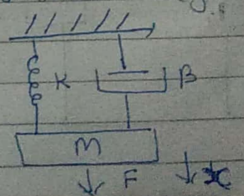
① $T = J\frac{d^2\theta}{dt^2}$ (Torque)



② $T = B\frac{d\theta}{dt}$ (damping)

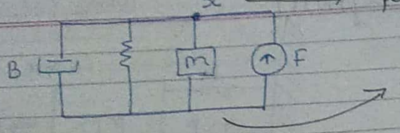
D'Alembert's

→ this principle State's that for any System the algebric sum of externally applied forces and the forces resisting motion in a given direction is zero.



displacement (x) — o/p
Force ——— i/p

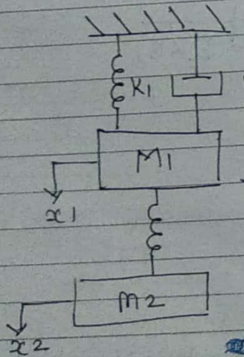
$x \longrightarrow$ principle node



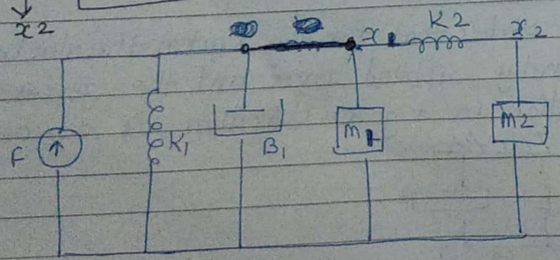
$$F = M\frac{d^2x}{dt^2} + Kx + B\frac{dx}{dt}$$

$$F(s) = Ms^2x + KX(s) + BSX(s)$$

Q



Solve.



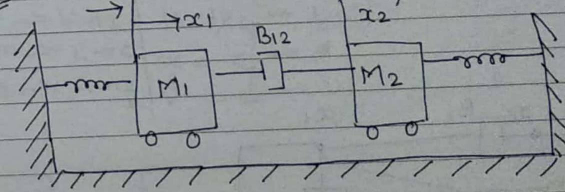
frictionless — No force

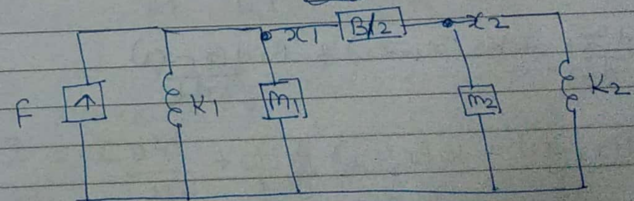
$$0 = K_2(x_2 - x_1) + M_2\frac{d^2x_2}{dt^2} = 0$$

$$F = K_1x_1 + B_1\frac{dx_1}{dt} + m_1\frac{d^2x_1}{dt^2} + K_2(x_1 - x_2)$$

$$\frac{x(s)}{F(s)}$$

Q

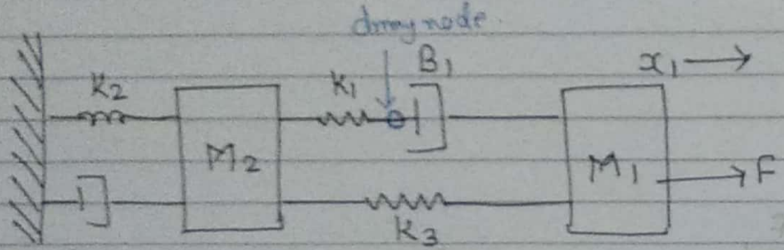


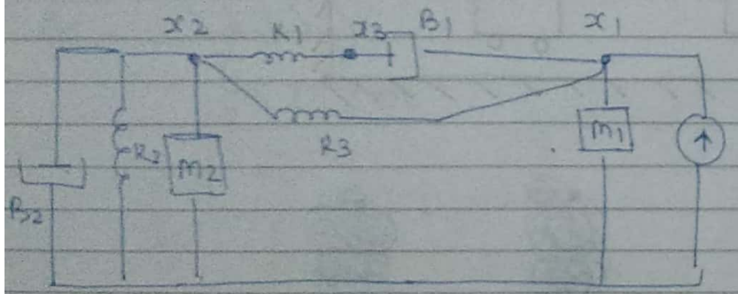


$$F = K_1x_1 + M_1\frac{d^2x_1}{dt^2} + \frac{B(x_1 - x_2)}{2\,dt}$$

$$0 = K_2x_2 + M_2\frac{d^2x_2}{dt^2} + \frac{B(x_2 - x_1)}{2\,dt}$$

Q



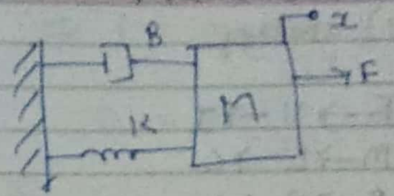


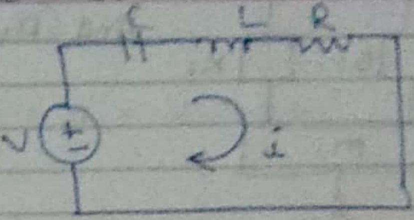
$$F = m_1\frac{d^2x_1}{dt^2} + K_3(x_1 - x_2) + B_1\frac{d(x_1 - x_3)}{dt}$$

$$0 = B_1\frac{d(x_3 - x_1)}{dt} + k_1(x_3 - x_2)$$

$$0 = m_2\frac{d^2x_2}{dt^2} + K_1(x_2 - x_3) + K_3(x_2 - x_1) + K_2x_2 + B\frac{dx_2}{dt}$$

Machanical to Electrical.





$$F = m\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx$$

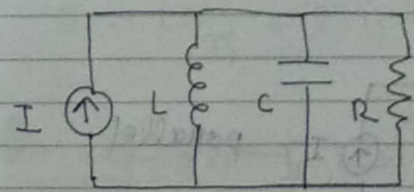
$$V = \frac{1}{C}\int i\,dt + L\frac{di}{dt} + Ri$$

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

$$V = L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{1}{C}q \qquad V = \frac{1}{C}q + L\frac{d^2q}{dt^2} + R\frac{dq}{dt}$$

$\Rightarrow$

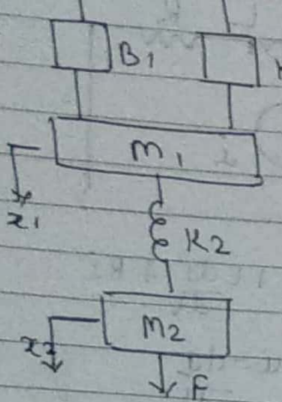
$F \to V \to I$	$K = 1/C \to \frac{1}{L}$
$M \to L \to C$	$x = q \to \phi$
$B \to R \to \frac{1}{R}$	$v = i \to V$



$$I = C\frac{dv}{dt} + \frac{1}{L}\int v\,dt + \frac{V}{R}$$

$$V = \frac{d\phi}{dt}$$

$$I = C\frac{d^2\phi}{dt^2} + \frac{1}{L}\phi + \frac{1}{R}\frac{d\phi}{dt}$$



find f(v) f(I) analogy.

$F \rightarrow V \rightarrow I$

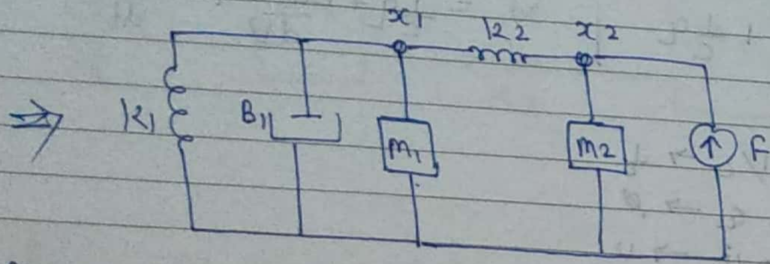
$M \rightarrow L \rightarrow C$

$B \rightarrow R \rightarrow \frac{1}{R}$

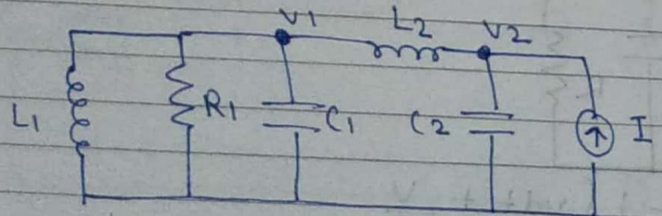
$K \rightarrow \frac{1}{C} \rightarrow \frac{1}{L}$

$x \rightarrow q \rightarrow \phi$

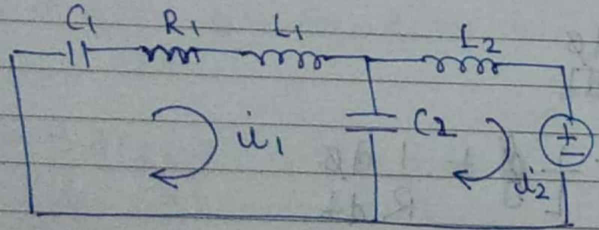
$v \rightarrow i \rightarrow V$



Current analogy



parallel



Series.

...ly add in current case when they are parallel.

For Current

$$\Rightarrow F = M_2\frac{d^2x_2}{dt^2} + K_2(x_2-x_1)$$

$$0 = M_1\frac{d^2x_1}{dt^2} + B_1\frac{dx_1}{dt} + K_1x_1 + K_2(x_1-x_2)$$

$$I = C_2\frac{d^2\phi_2}{dt^2} + \frac{1}{L_2}(x_2-x_1)$$

$$I = C_2\frac{dv_2}{dt} + \frac{1}{L_2}\int(v_2-v_1)dt$$

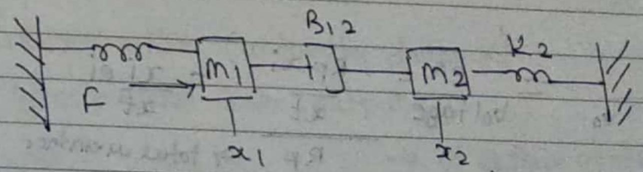
$$0 = C_1\frac{dv_1}{dt} + \frac{1}{R_1}v_1 + \frac{1}{L_1}\int v_1 dt + \frac{1}{L_2}\int(v_1-v_2)dt$$

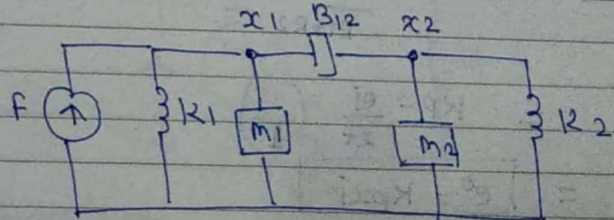
For voltage.

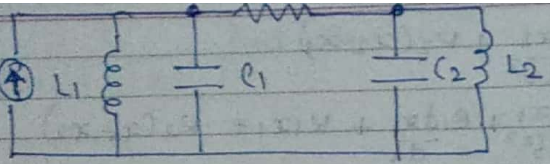
$$V = L_2\frac{di_2}{dt} + \frac{1}{C_2}\int(i_2-i_1)dt$$

$$0 = L_1\frac{di_1}{dt} + R_1 i_1 + \frac{1}{C_1}\int i_1 dt + \frac{1}{C_2}\int(i_1-i_2)dt$$

Q

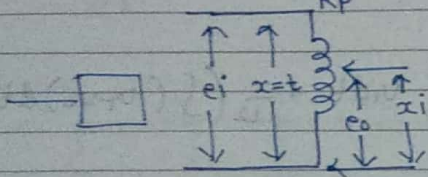






Components

① potentiometer



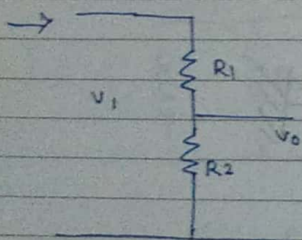
e_0 — o/p
x_i — i/p

① input → x_i
② output → e_0

③ R_p → total resistence of the potentiometer.
④ Resistence / Unit length → $\frac{R_p}{x_t}$

$\frac{R(s)}{X_i(s)}$ → [G(s)] → $\frac{C(s)}{E_0(s)}$

⑤ $R \cdot x_i \rightarrow \frac{R_p \cdot x_i}{x_t}$



$= \dfrac{e^0 = \text{Voltage}}{} = \dfrac{\frac{R_p \cdot x_i}{x_t}}{R_p} = \dfrac{x_i\, e_i}{x_t}$

R_p → total resistance

$= V_0 = \frac{R_2}{R_1+R_2} \cdot V_i$

$X_i(s)$ → [Kp] → $E_0(s)$

$= K_p = \frac{e_i}{x_t} \left(\frac{V}{l}\right)$

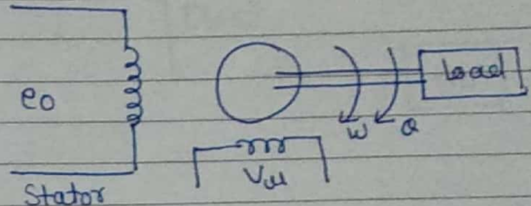
$= \boxed{e^0 = K_p x_i}$

k_p is total gain of the potentiometer $= E_0(s) = K_p X_i(s)$

② Tachometer < dc

It is used for checking Speed of the motor.

ac → two phase induction motor



input → ω (angular velocity)
e_0 → output

$e_0 \propto \omega$
$e_0 = K_T \omega$
$E_0(s) = K_T\, \omega(s) \longrightarrow s\theta(s)$

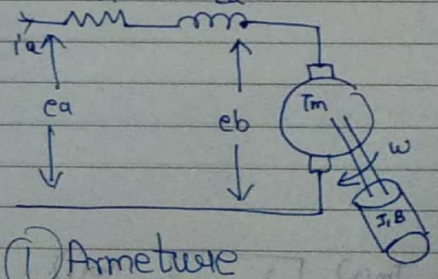
$\omega(s)$ → [KT] → $E_0(s)$

$\theta(s)$ → [S] → [KT] → $E_0(s)$

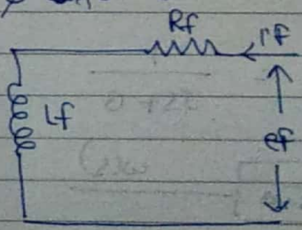
③ Servomotor (internally feedback)

It gives perticise Control output.

→ Ø flux generated through current



① Armeture winding



② Field winding

· speed depend upon back emf

① i/p → e_a
o/p → ω

$\phi \propto i_f$

$\boxed{\phi = K_f i_f}$

$T_m \propto \phi i_a$

$T_m = \underbrace{K_1 K_f i_f}_{K_T \;\to\; \text{motor constant}} i_a$

$\boxed{T_m = K_T i_a}$, laplace, $T_m(s) = K_T I_a(s)$ —— ②

$e_a - e_b = i_a R_a + L_a \dfrac{di_a}{dt}$, Laplace, $E_a(s) - E_b(s) = I_a(s) R_a + sL_a I_a(s)$ ③

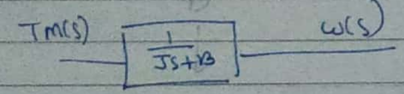
$T_m = J\dfrac{d^2\theta}{dt^2} + B\dfrac{d\theta}{dt}$

$T_m = J\dfrac{d\omega}{dt} + B\omega$, $T_m(s) = (sJ + B)\,\omega(s)$ —— ①

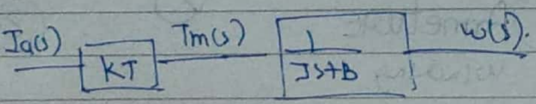
$e_b \propto \omega$

$\boxed{e_b = K_b \omega}$, $E_b(s) = K_b \omega(s)$

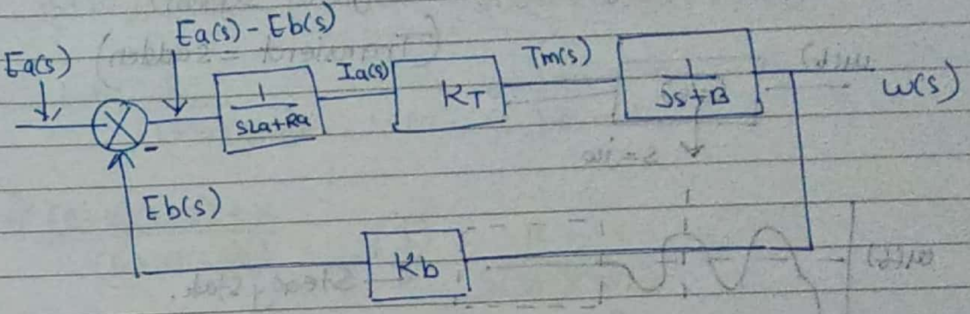
① $\dfrac{C(s)}{R(s)}$ $\dfrac{\omega(s)}{T_m(s)} = \dfrac{1}{Js + B}$



② $\dfrac{T_m(s)}{I_a(s)} = K_T$



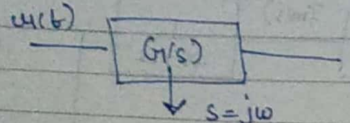
③ from ③

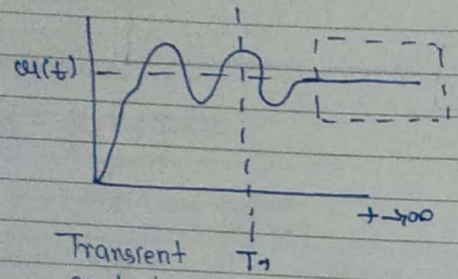


Time domain Analysis

→ Transient analysis (order of System)
→ steady state (type of System)

(Transient = sudden)





→ Total no. of poles at origin is the type of system.
→ always we open loop transfer function = $G(s)\,H(s)$
→ order of the system always calculated the characteristic equation of system. $1+G(s)H(s)$ → highest degree is order.

Unity feedback system — $H(s)=1$

Q $G(s) = \dfrac{(s+2)(s+3)}{s^2(s+1)(s+5)}$ unity feedback.

using $1+G(s)H(s)$ for order.

$$1+\frac{(s+2)(s+3)}{s^2(s+1)(s+5)} = \frac{s^2(s+1)(s+5)+(s+2)(s+3)}{s^4}$$

order of the System is 4

① $\dfrac{K}{(s+10)(s+5)}$

$= 1+\dfrac{K}{(s+10)(s+5)}$

$\Rightarrow \dfrac{(s+10)(s+5)+K}{(s+10)(s+5)}$

$\Rightarrow$ order = 2
poles = 0

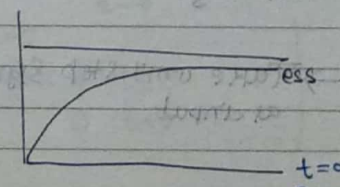
② $\dfrac{2.0}{s(0.1+0.1s)(1+0.5s)}$

order = 3
Type = 1

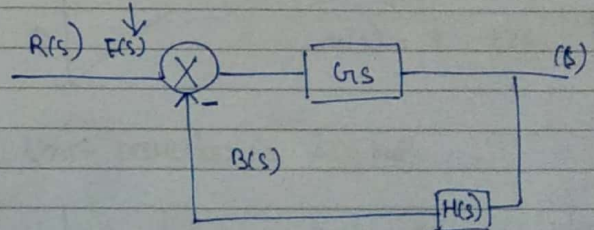
③ $\dfrac{K}{s(s+1)(s+2)}$

order = 3
type = 1

Steady state error:



$\lim\limits_{t\to\infty} e(t) = \lim\limits_{s\to 0} s\,E(s)$

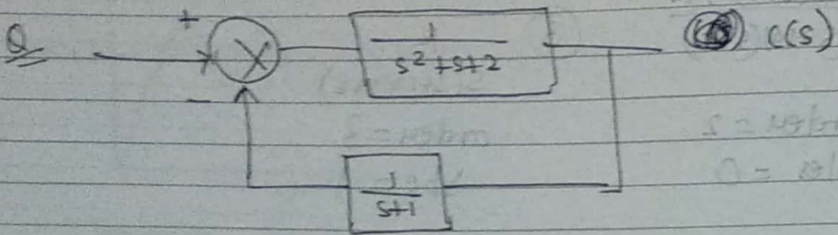


$E(s) = R(s) - B(s)$
$= R(s) - C(s)\,H(s)$
$= R(s) - E(s)\,G(s)\,H(s)$

$(1+G(s)H(s))\,E(s) = R(s)$

$$E(s) = \frac{R(s)}{1+G(s)H(s)}$$

$$\lim_{t\to\infty} e(t) = \lim_{s\to 0} sE(s) \quad \lim_{s\to 0} \frac{sR_s}{1+G(s)H(s)}$$



$$e_{ss} = \lim_{s\to 0} \frac{sR(s)}{1+G(s)H(s)} \quad , \quad u(t) = u(t) \quad R(s) = \frac{1}{s}$$

$$\lim_{s\to 0} \frac{s\times\frac{1}{s}}{1+\left(\frac{1}{s^2+s+2}\right)\left(\frac{1}{s+1}\right)}$$

→ Take unit step signal as input

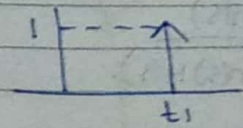
$$e_{ss} = \frac{2}{3}$$

Lablace $\{\delta(t)\} = 1$

Signals

$$\boxed{L\{t^n\} = \frac{n!}{s^{n+1}}}$$

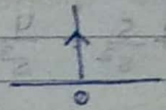
① Unit impulse signal at t1



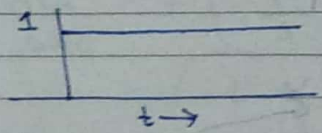
area = 1

$$\delta(t-t_1) = 1 \Big|_{t=t_1}$$

$$\delta(t) = 1/_{t=0}$$



② Unit step signal
Step of fix unit



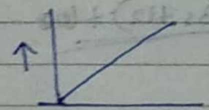
bounded input

t=0

$$u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$$

$L\{u(t)\} = 1/s$

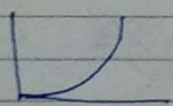
③ (Constant) Unit ramp Signal



$r(t) = t \quad t > 0$

$L\{r(t)\} = 1/s^2$

④ Unit parabolic Signal.



$P(t) = t^2$

$L\{P(t)\} = 2/s^3$

Q: $H(s) = 1$ For Close loop.

$$G(s) = \frac{108}{s^2(s+4)(s^2+3s+12)} \qquad \frac{G(s)}{1+G(s)H(s)}$$

$r(t) = 2+5t+2t^2.$

$$R(s) = \frac{2}{s} + \frac{5}{s^2} + \frac{4}{s^3}$$

$$\lim_{s\to 0} = \frac{s\times\left(\frac{2}{s}+\frac{5}{s^2}+\frac{4}{s^3}\right)}{1+\left(\frac{108}{s^2(s+4)(s^2+3s+12)}\right)\times 1}$$

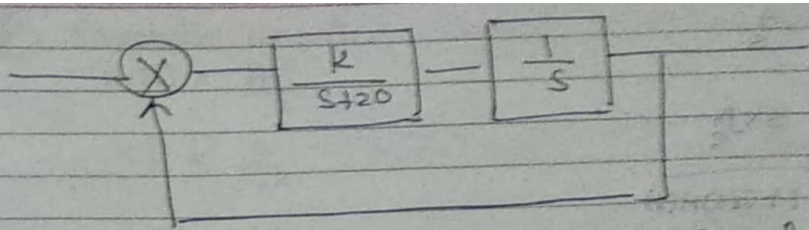
$$\Rightarrow \frac{s\left(\frac{2s^2+5s+4}{s^3}\right)}{\frac{s^2(s+4)(s^2+3s+12)+108}{s^2(s+4)(s^2+3s+12)}}$$

— multiply by highest power s^3.

$$\Rightarrow = \frac{2s^2+5s+4 \times s^2(s+4)(s^2+3s+12)}{s^2\times s^2 (s+4)(s^2+3s+12)+108}$$

$$\Rightarrow \frac{4}{\frac{108}{4\times 12}}$$

$\Rightarrow 1.77.$



① $K = 400$ input ramp signal.

$R(s) = \frac{1}{s^2}$ $H(s) = 1$

$$G(s) = \frac{K}{s^2+20s}$$

$$\lim_{s\to 0} = \frac{\left(\frac{1}{s}\right)\times s}{\left(1+\left(\frac{K}{s^2+20s}\right)\right)\times s} = \frac{\frac{1}{s}}{\frac{s^2+20s+K}{s^2+20s}}$$

$$= \frac{s^2+20s}{s^3+20s^2+Ks}$$

$$= \frac{s^2+20s}{s^3+20s^2+400s}$$

$$= \frac{\cancel{s}(s+20)}{\cancel{s}(s^2+20s+400)} = \frac{\cancel{s}+20}{\cancel{s^2}+\cancel{20s}+400}$$

$$\lim_{s\to 0} = \frac{20}{400} = \frac{1}{20} = 0.05$$

② → $e_{ss} = 0.02$, $K = ?$

$$0.02 = \frac{20}{K}$$

$= 1000.$

a) Step input $\frac{A}{s}$

$$e_{ss} = \lim_{s=0} \frac{s \times \frac{A}{s}}{1+G(s)H(s)}$$

$$e_{ss} = \frac{A}{1+G(s)H(s)}$$

$K_p \rightarrow$ positional error Constant ↓ $e_{ss} = \frac{A}{1+K_p}$ ↑

$$\boxed{K_p = \lim_{s \to 0} G(s)H(s)}$$

b) Ramp input

$r(t) = At$

$R(s) = \frac{A}{s^2}$

$$e_{ss} = \lim_{s \to 0} \frac{s \times \frac{A}{s^2}}{1 + \lim_{s \to 0} G(s)H(s)}$$

$$= \lim_{s \to 0} \left[\frac{A}{s + sG(s)H(s)} \right]$$

$$= \lim_{s \to 0} \left[\frac{A}{sG(s)H(s)} \right]$$

$$= \frac{A}{K_V}$$

$K_V \rightarrow$ velocity error Coefficient

$$\boxed{K_V = \lim_{s \to 0} sG(s)H(s)}$$

© Parabolic input

$r(t) = \frac{At^2}{2}$

$R(s) = \frac{A}{s^3}$

$$e_{ss} = \lim_{s \to 0} \frac{s\frac{A}{s^2}}{1 + \lim_{s \to 0} G(s)H(s)}$$

$$= \lim_{s \to 0} \left[\frac{A}{s^2 + s^2G(s)H(s)} \right]$$

$$= \lim_{s \to 0} \left[\frac{A}{s^2G(s)H(s)} \right] = \frac{A}{K_A}$$

$K_A \rightarrow$ Acceleration error Coefficient

$$\boxed{K_A = \lim_{s \to 0} s^2 G(s)H(s)}$$

Q. ~~[illegible]~~ openloop system unity feedback system, find static error Constant. K_P, K_V, K_A?

$$G(s) = \frac{50}{(1+0.1s)(s+10)}$$

$$e_{ss} = \frac{50}{(1)(10)} = 5$$

$K_p = 5$

Q $G(s) = \frac{K(1+T_1 s)}{(1+T_2 s)}$ Steady State error

① $\lim_{s\to 0} \dfrac{s\frac{A}{s}}{1+\frac{K(1+T_1 s)}{(1+T_2 s)}}$ Step Unit

$$e_{ss} = \frac{A}{1+K}$$

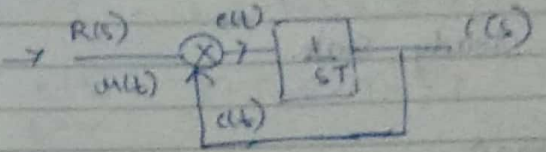
② ramp input

$$\lim_{s\to 0} \frac{s\frac{A}{s^2}}{1+K\frac{(1+T_1 s)}{(1+T_2 s)}} \rightarrow \frac{A(1+T_2 s)}{s(1+K(1+T_1 s))} \rightarrow \frac{A(1+T_2(s))}{s+s\cdot K(1+T_1 s)}$$

$$e_{ss} = \infty$$

even for further values → value will be 0.
same, in Type(1) system for first input value will be 0 and for further inputs value will be some constant value.

→ $\frac{1}{1+TS}$ order = 1

→ 

error $e(t) = R(t) - c(t)$

$$\Rightarrow \frac{\frac{1}{ST}}{1+\frac{1}{ST}} \Rightarrow \frac{1}{ST+1}$$

① $u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & \infty \end{cases}$

$$R(s) = \frac{1}{S}$$

$$\frac{C(s)}{R(s)} = \frac{1}{1+ST}$$

$$C(s) = \frac{1}{1+ST} R(s)$$

$$\Rightarrow \frac{1}{S}\left(\frac{1}{1+ST}\right)$$

$$C(s) = \frac{1}{S(1+ST)} \Rightarrow \frac{A}{S} + \frac{B}{1+ST}$$

$$\Rightarrow \frac{1}{S} - \frac{T}{1+ST} \rightarrow \text{time constant}$$

Q $L^{-1}[C(s)] = \left[\frac{1}{s} - \frac{1}{s+\frac{1}{T}}\right]$

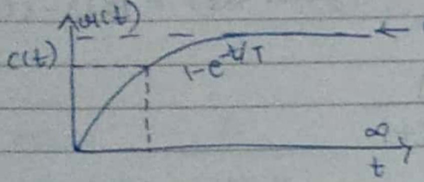
$$C(t) \Rightarrow 1 - e^{-t/T}$$

$e(t) = r(t) - c(t)$

$= 1-(1-e^{-t/T})$

$= e^{-t/T}$

$\lim_{t\to\infty} e(t) = 0$ in steady state.



(time) $t = T$ (time constant)

$1-e^{-T/T}$

$\Rightarrow 1-e^{-1}$ (put $t=T$)

$1-0.638$

$\Rightarrow 0.63$

$T\uparrow$ System slow

$T\downarrow$ System fast

Ramp input

$r(t)=t$

$R(s)=\frac{1}{s^2}$

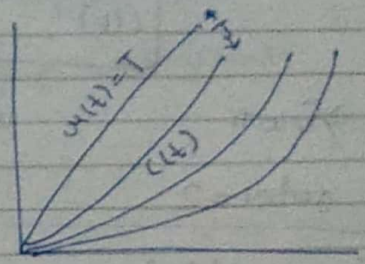
$C(s)=\frac{1}{s^2(1+sT)}$

$C(s) = \frac{A}{s}+\frac{B}{s^2}+\frac{C}{1+sT}$ $\quad A=-T \quad B=1, \quad C=T^2$

$= \frac{-T}{s}+\frac{1}{s^2}+\frac{T^2}{1+sT}$

$\Rightarrow \frac{-T}{s}+\frac{1}{s^2}+\frac{T}{s+\frac{1}{T}}$

$c(t) = -T+t+Te^{-t/T}$



$e(t) = r(t) - c(t)$

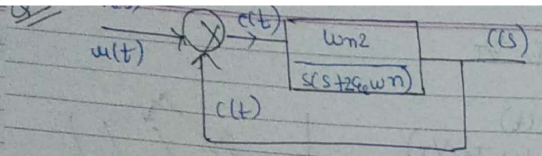
$= t-(-T+t+Te^{-t/T})$

$\lim_{t\to\infty} e(t) = \cancel{t}+T-\cancel{t}-Te^{-t/T}$

$= T$

impulse input

Scanned by CamScanner



$\Rightarrow \xi\omega_n$ $\qquad r(t) = \delta(t)$

order = 2

$$\boxed{T = \frac{\omega_n^2}{s^2+2\xi\omega_n+\omega_n^2} = \frac{C(s)}{R(s)}}$$

Step input $R(s) = 1/s$ $\qquad$ Characteristic eqn.

$$s^2+2\xi\omega_n s+\omega_n^2 = 0$$

$$C(s) = \frac{1}{s}\left(\frac{\omega_n^2}{s^2+2\xi\omega_n+\omega_n^2}\right)$$

$$= \frac{1}{s}\left(\frac{\omega_n^2}{s^2+2\xi\omega_n+\omega_n^2+\xi^2\omega_n^2-\xi^2\omega_n^2}\right)$$

$$= (s+\xi\omega_n)^2+\omega_n^2(1-\xi^2)$$

$\omega_d^2 = \omega_n^2(1-\xi^2)$ $\qquad$ damping frequency.

$\omega_d = \omega_n\sqrt{1-\xi^2}$

$$C(s) = \frac{1}{s}\frac{\omega_n^2}{((s+\xi\omega_n)^2+\omega_d^2)}$$

$$C(s) = \frac{A}{s}+\frac{Bs+C}{(s+\xi\omega_n)^2+\omega_d^2} \qquad \text{taking P.F}$$

$$= \frac{1}{s}+\frac{s+2\xi\omega_n}{(s+\xi\omega_n)^2+\omega_d^2}$$

$$\boxed{\frac{a}{s^2+a^2},\ \frac{s}{s^2+a^2},\ \frac{(s+b)}{(s+b)^2+a^2}.}$$

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$$\Rightarrow \frac{1}{s}+\frac{s+\xi\omega_n}{(s+\xi\omega_n)^2+\omega_d^2}+\frac{\xi\omega_n\omega_d}{\omega_d((s+\xi\omega_n)^2+\omega_d^2)}$$

$$\Rightarrow 1+e^{-\xi\omega_n t}\cos\omega_d t+\frac{\xi\omega_n}{\omega_d}e^{-\xi\omega_n t}\sin\omega_d t$$

$$\boxed{\frac{\xi\omega_n}{\omega_d} \Rightarrow \frac{\xi}{\sqrt{1-\xi^2}}}$$

$$c(t) = 1+e^{-\xi\omega_n t}\cos\omega_d t+\frac{\xi}{\sqrt{1-\xi^2}}e^{-\xi\omega_n t}\sin\omega_d t$$

$$\Rightarrow = 1+\frac{e^{-\xi\omega_n t}}{\sqrt{1-\xi^2}}\left[\sqrt{1-\xi^2}\cos\omega_d t+\xi\sin\omega_d t\right]$$

take $\xi = \cos\phi$

$\sqrt{1-\xi^2} = \sin\phi$

$$\Rightarrow \tan\phi = \frac{\sqrt{1-\xi^2}}{\xi}$$

$$\Rightarrow 1+\frac{e^{-\xi\omega_n t}}{\sqrt{1-\xi^2}}\left[\sin\phi\cos\omega_d t+\cos\phi\sin\omega_d t\right]$$

$$c(t) \Rightarrow 1+\frac{e^{-\xi\omega_n t}}{\sqrt{1-\xi^2}}\sin\left[\omega_d t+\phi\right]$$

Steady state error $t \Rightarrow \infty$

$\Rightarrow 1$

= Characteristic equation of second order System $s^2+2\xi\omega_n s+\omega_n^2 = 0$

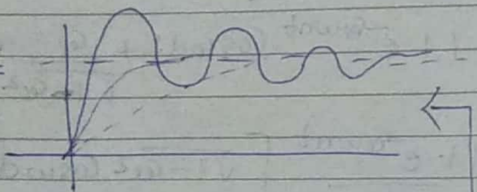
damping ↓
need for steady state

using $b^2 - 4ac$

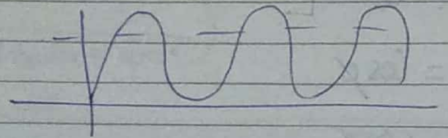
$$S_{1,2} = \underbrace{-\zeta\omega_n}_{\text{damping factor}} \pm \underbrace{j\omega_n\sqrt{1-\zeta^2}}_{\text{damping freq.}}$$

$= -\zeta\omega_n \pm j\omega_d$

- damping factor = $-\zeta\omega_n \pm j\omega_d$



- $\zeta = 0$
→ undamped



$\frac{1}{s^2+\omega_n^2}$

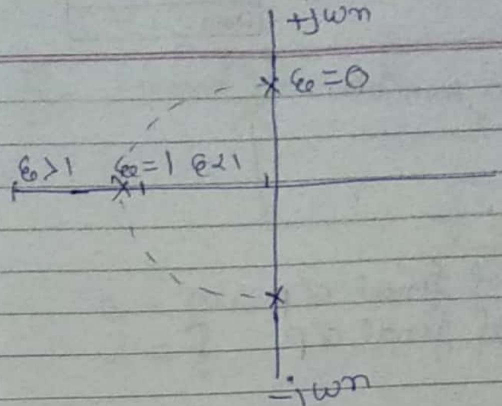
→ Output can be stable.

- $0 < \zeta < 1$ → Underdamped System
- $\zeta > 1$ → overdamped system

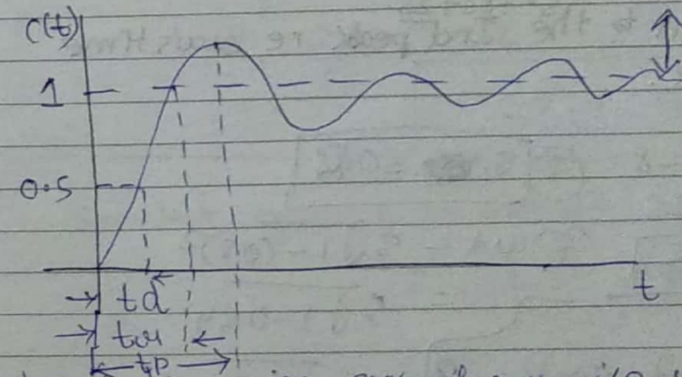
$\pm e^{-at} \pm e^{-bt} = \frac{1}{(s+a)(s+b)}$

- $\zeta = 1$ → critically damped system

$\frac{1}{(s+a)^2}$



- damping coef. $\alpha = \zeta\omega_n$
- " factor
- " freq. $\omega_d = \omega_n\sqrt{1-\zeta^2}$
- Time Constant $T = \frac{1}{\alpha}$



for step unit

- when system arise 50% of our i/p value this called delay time

$t_d = \frac{1+0.7\zeta}{\omega_n}$ (time delay)

$t_r = \frac{\pi-\phi}{\omega_d}$ $(c(t)=1)$ (time rise)

$\phi = \tan^{-1}\left(\frac{\sqrt{1-\zeta^2}}{\zeta}\right)$

- Peak time

$t_p = \frac{n\pi}{\omega_d}$ $n \rightarrow$ odd number

- Settling time

$t_s = 4T$ for 2% of final o/p

$3T$ for 5% of final o/p

- Max. Peak overshoot

$M_p = e^{\frac{-\zeta n\pi}{\sqrt{1-\zeta^2}}}$

Q. S.O.S, $G(s) = \frac{25}{s^2+8s+25}$ for step input

find time taken to the 2nd peak i.e. occurs time for 2nd peak.

Solve (1) $2\zeta\omega_n - 8$

$\omega_n^2 - 25$

$\boxed{\omega_n = 5}$

(2) $\boxed{\zeta = 0.8}$

(3) $\omega_d = 5\sqrt{1-(0.8)^2}$

$= 5\sqrt{1-0.64}$

$= 5\sqrt{0.36}$

$= 5 \times 0.6$

$\boxed{\omega_d = 3.0}$

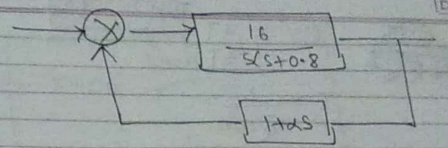
(4) $n =$ for second peak $= 3$

$t_p = \frac{n\pi}{\omega_d}$

$t_p = \frac{3 \times 3.14}{3.0}$

$\boxed{t_p = 3.14}$

Q.



$t_s = ?$

$\zeta = 0.5$

$\alpha = ?$

Given $\zeta = 0.5$

transfer fun^n. $= \frac{\frac{16}{s(s+0.8)}}{1 + \frac{16}{s(s+0.8)} \cdot 1+\alpha s}$

$T_1 \Rightarrow \frac{16}{s(s+0.8) + 16(1+\alpha s)}$

Characteristic eqn. $= 1 + G(s)H(s)$

$1 + \frac{16}{s(s+0.8)} \cdot 1+\alpha s = 0$

$= s(s+0.8) + 16 + 16\alpha s$

$= s^2 + 0.8s + 16 + 16\alpha s$

$= s^2 + (0.8 + 16\alpha)s + 16$

$= s^2 + 2\zeta\omega_n s + \omega_n^2$

$\rightarrow \omega_n^2 = 16$

$\rightarrow 2\zeta\omega_n = (0.8 + 16\alpha)$

$2 \times 0.5 \times 4 = 0.8 + 16\alpha$

$\boxed{\omega_n = 4}$

$\boxed{\alpha = 0.2}$

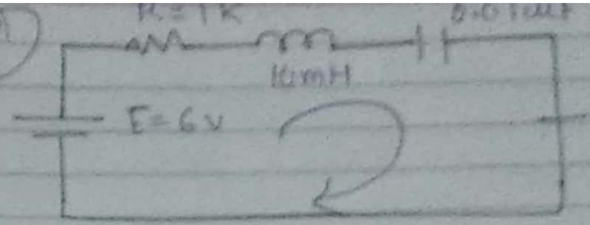
$$t_s = 4T$$
$$3T$$

$$T = \frac{1}{\xi \omega_n}$$

Now, for settling time $t_s = 3T$
$4T$.

after that, $M_p = e^{-\left(\frac{\xi\pi}{\sqrt{1-\xi^2}}\right)}$

1.



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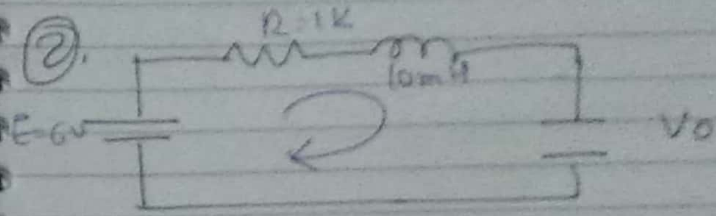

$$\frac{V_o}{E} = \frac{1}{LCs^2 + RCs + 1}$$