

Q. 1. A

Defⁿ - In case of Block dig redⁿ tech, successive applicatⁿ of Block dig. redⁿ rule are required to obtain overall T.F, So it is time consuming.

SFG uses single formula to obtain T.F., i.e. known as Mason's gain formula.

$$T.F. = \frac{C(s)}{R(s)} = \frac{\sum F_i \Delta_i}{\Delta}$$

Where i = no. of Forward path

F_i = Gain of i th forward path

Δ = S/m determinant.

$\Delta = 1 - (\text{Sum of all individual loop})$
 $+ (\text{sum of all gain product of two non-touching loops})$
 $- (\text{3 non touching loop})$

$\Delta_i = 1 - \text{all the loops that do not touch to } i\text{th Forward path.}$

Q. 2. B

open loop	closed loop
1. no f/b,	1. F/b exists.
2. No error detector	2. error detector present
3. stable	3. may become unstable
4. Small BW	4. large BW
5. Economical	5. Costly
6. inaccurate	6. accurate
7. highly sensitive	7. less sensitive
8. examples : coffee maker	8. Guided missile etc.

(C) → defⁿ of relative stability (2 mks)

→ relative stability related to settling time
so relⁿ betⁿ T_s & Relative stability
(3 mks)

(D) → explanation of two paradigms i.e.
fuzzy logic & Neural net (1 mks)

→ advantages of neuro fuzzy logic (1 mks)

→ dig. (2 mks)

→ explanation (1 mks)

Q. 2

$$G(s) = \frac{20}{s(1+4s)(1+s)}$$

→ static error coefficients.

(Type 1 s/m)

— (1 mks)

$$K_p = \lim_{s \rightarrow 0} \frac{20}{s(1+4s)(1+s)} = \infty \quad 1 \text{ mks}$$

$$K_v = \lim_{s \rightarrow 0} s \cdot G(s)H(s) = 20 \quad 1 \text{ mks}$$

$$K_a = \lim_{s \rightarrow 0} s^2 G(s)H(s) = 0 \quad 1 \text{ mks}$$

Steady state error

$$r(t) = 2 + 4t + \frac{t^2}{2} \quad \text{i/p is made}$$

up of step of mag. 2, ramp of mag. 4
& parabola of mag. 1.

$$e_{ss} \text{ for Step} = \frac{A}{1+K_p} = 0 \quad (1 \text{ mks})$$

$$e_{ss} \text{ for ramp} = \frac{A}{K_v} = \frac{4}{20} \quad (1 \text{ mks})$$

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$$e_{ss} \text{ for parabola} = \frac{A}{K_a} = \infty \quad (1 \text{ mks})$$

$$(1 \text{ mks}) \quad e_{ss} \text{ total} = e_{ss}|_{\text{step}} + e_{ss}|_{\text{ramp}} + e_{ss}|_{\text{parabola}}$$

$$\boxed{e_{ss} = \infty} \quad (2 \text{ mks})$$

Q. 2 (B)

$$(a) \quad s^6 + 2s^5 + 8s^4 + 12s^3 + 20s^2 + 16s + 16 = 0$$

Routh's array

s^6	1	8	20	16
s^5	2	12	16	0
s^4	2	12	16	0
s^3	0	0	0	

2 mks

s^3 row is 0

auxiliary eqⁿ

$$A(s) = 2s^4 + 12s^2 + 16$$

$$\frac{dA(s)}{ds} = 8s^3 + 24s$$

s^6	1	8	20	16
s^5	2	12	16	0
s^4	2	12	16	0
s^3	8	24	0	
s^2	6	16	0	
s^1	2.67	0		
s^0	16			

2 mks

No sign change, s/m is stable.

} solving auxiliary eqⁿ we get

$$2s^4 + 12s^2 + 16 = 0$$

$$\text{by solving we get } s = \pm j\sqrt{2}$$

Non-repeated roots on jw axis $\pm 2j$
marginally stable

1 mks

1 mks

04

Q. 2 (B) (b) $s^5 + 2s^4 + 3s^3 + 6s^2 + 2s + 1 = 0$

s^5	1	3	2
s^4	2	6	1
s^3	0	1.5	0
s^2	∞		

replace 0 by ϵ

s^5	1	3	2
s^4	2	6	1
s^3	ϵ	1.5	0
s^2	$\frac{6\epsilon-3}{\epsilon}$	1	0
s^1	$\frac{1.5 \left(\frac{6\epsilon-3}{\epsilon} \right) - \epsilon}{\left(\frac{6\epsilon-3}{\epsilon} \right)}$	0	
s^0	1		

1) $\lim_{\epsilon \rightarrow 0} \frac{6\epsilon-3}{\epsilon} = -\infty$

2) $\lim_{\epsilon \rightarrow 0} \frac{1.5 \left(\frac{6\epsilon-3}{\epsilon} \right) - \epsilon^2}{6\epsilon-3} = 1.5$

draw the root array table

$\rightarrow$ two sign changes, s/m unstable
(1 m/s)

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Q. 3 (a)

$$G(s) = \frac{25}{s^2 + 6s + 25}$$

Find T_r, T_p, M_p
 $\leftarrow T_s$

→ Compare the given s/m with
std. 2nd order eqⁿ.

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

3 mks
(1 mks for each)

$$\omega_n = 5 \text{ rad/sec} \quad \zeta = \frac{6}{2\omega_n} = 0.6$$

$$\omega_d = \omega_n \sqrt{1 - \zeta^2} = 4 \text{ rad/sec}$$

2 mks

$$\theta = \tan^{-1} \left[\frac{\sqrt{1 - \zeta^2}}{\zeta} \right] = 0.927 \text{ radian}$$

5 mks
1 mks for each

$$T_r = \frac{\pi - \theta}{\omega_d} = 0.55 \text{ sec}$$

$$T_p = \frac{\pi}{\omega_d} = 0.785 \text{ sec}$$

$$T_s = \frac{4}{\zeta\omega_n} = 1.33 \text{ sec}$$

$$\% M_p = \frac{e^{-\frac{\zeta\pi}{\sqrt{1 - \zeta^2}}}}{e^{\frac{\zeta\pi}{\sqrt{1 - \zeta^2}}}} \times 100$$

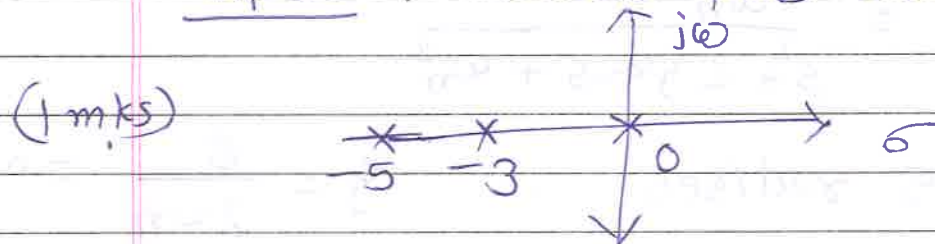
$$= 9.487 \%$$

$$c(t) = 1 - 1.25 e^{-3t} \sin$$

Q. 3 (B) $G(s) = \frac{K}{s(s+3)(s+5)}$

→ Step 1: no. of loci & loci ending at ∞ .
 (1 mks) no. of loci = 3
 no. of loci ending at $\infty = p - z = 3$

Step 2: draw pole zero plot



Step 3: ~~the~~ real axis loci

(1 mks) $-3 < s < 0 \rightarrow$ present, absent $\rightarrow -5 < s < -3$
 present $-\infty < s < -5$

Step 4: asymptotes & angle -

(2 mks) a) no. of asymptotes = $p - z = 3$

b) angle $\beta_0 = 60^\circ$, $\beta_1 = 180^\circ$, $\beta_2 = 300^\circ$

Step 5: Centroid

(1 mks) $\sigma_c = -2.667$

Step 6: Break away pt.

(1 mks) solve characteristic eqⁿ & we get
 $s = -4.11$ & $s = -1.21$
 $s = -1.21$ is valid Breakaway pt.

Step 7: angle of departure $\rightarrow$ no

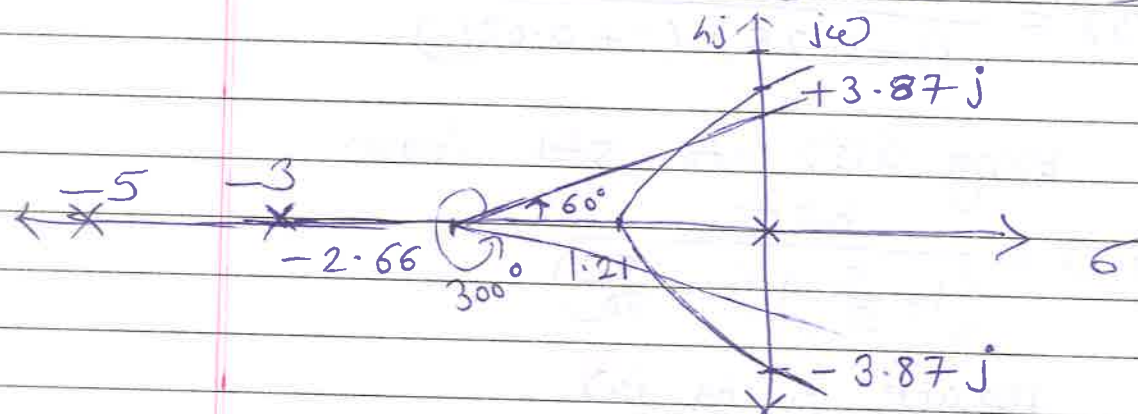
Step 8: Intersectⁿ with imaginary axis
 solve by Routh array method, we get

(1 mks)

$K = 120$

by work with auxiliary eqⁿ we
 $s = \pm 3.87j$

→ final root locus (2mks)



Q. 4 (A)

① no. of Forward path

(1 mks)

$$F_1 = G_4, F_2 = G_1 G_2 G_3$$

② no. of single loop

(2mks)

$$L_{11} = -G_1 H_1$$

$$L_{21} = -G_1 G_2 H_2$$

$$L_{31} = -G_2 G_3 H_3$$

$$L_{41} = G_4 H_3 H_1$$

(1 mks) ③ no. of 2 non touching loop = 0

$$\Delta = 1 - (L_{11} + L_{21} + L_{31} + L_{41})$$

(2mks)

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

$$\Delta_1 = 1 - 0 = 1$$

(1mks)

$$\Delta_2 = 1 - 0 = 1$$

$$T = \frac{F_1 \Delta_1 + F_2 \Delta_2}{\Delta}$$

(1mks)

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

(2mks)

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Q. 4 (B)

$$G(s) = \frac{ks^2}{(1+0.2s)(1+0.02s)}$$

→ Step ① bring $G(s)$ into std form.

(1/2 mks)

$$G(s) = \frac{ks^2}{\left(1+\frac{s}{5}\right)\left(1+\frac{s}{50}\right)}$$

Step ② replace s by $j\omega$

(1/2 mks)

$$G(j\omega) = \frac{k(j\omega)(j\omega)}{\left(1+j\frac{\omega}{5}\right)\left(1+j\frac{\omega}{50}\right)}$$

Step ③

Factors	mag. curve	Phase curve
1) $(j\omega)^2$	Straight line of Slope = +40 dB/dec at 2 zero at origin passing thr. $[\omega=1, 0 \text{ dB}]$ pt.	$\phi = +180^\circ$
2) $1+j\frac{\omega}{5}$	line slopes are 1) 0 dB/dec $\omega < 5$ 2) -20 dB/dec $\omega > 5$	$\phi = -\tan^{-1}\frac{\omega}{5}$
3) $1+j\frac{\omega}{50}$	1) 0 dB/dec $\omega < 50$ 2) -20 dB/dec $\omega > 50$	$\phi = -\tan^{-1}\frac{\omega}{50}$

Step ⑤ magnitude plot table

Factor	Resultant slope	start pt. (ω)	end pt. (ω)
1) $(j\omega)^2$	+20 dB + 20 dB = +40 dB/dec	0.1	5
2) $1+j\frac{\omega}{5}$	+40 dB - 20 dB = +20 dB/dec	5	50
3) $1+j\frac{\omega}{50}$	+20 dB - 20 dB = 0 dB/dec	50	∞

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Step 6 The phase table is

$$\phi_{\text{Resultant}}(\omega) = 180^\circ + (-\tan^{-1} 0.2\omega) + (-\tan^{-1} 0.02\omega)$$

ω	$(j\omega)^2$	$-\tan^{-1} 0.2\omega$	$-\tan^{-1} 0.02\omega$	$\phi(\omega)$
0.1	+180	-1.14°	-0.11°	+178.7
5	+180	-45°	-5.7°	129.3°
(2 mks) 50	+180	-84.28	-45°	+50.72°
500	+180	-89.42	-84.28°	-6.3°
∞	+180	-90	-90°	-0°

Step 7:

$$\omega_{gc} = 5 \text{ rad/sec (Shift req is}$$

28 dB downwards from the graph)

(1 mks)

$$20 \log K = -28 \text{ dB}$$

$$K = 0.039$$

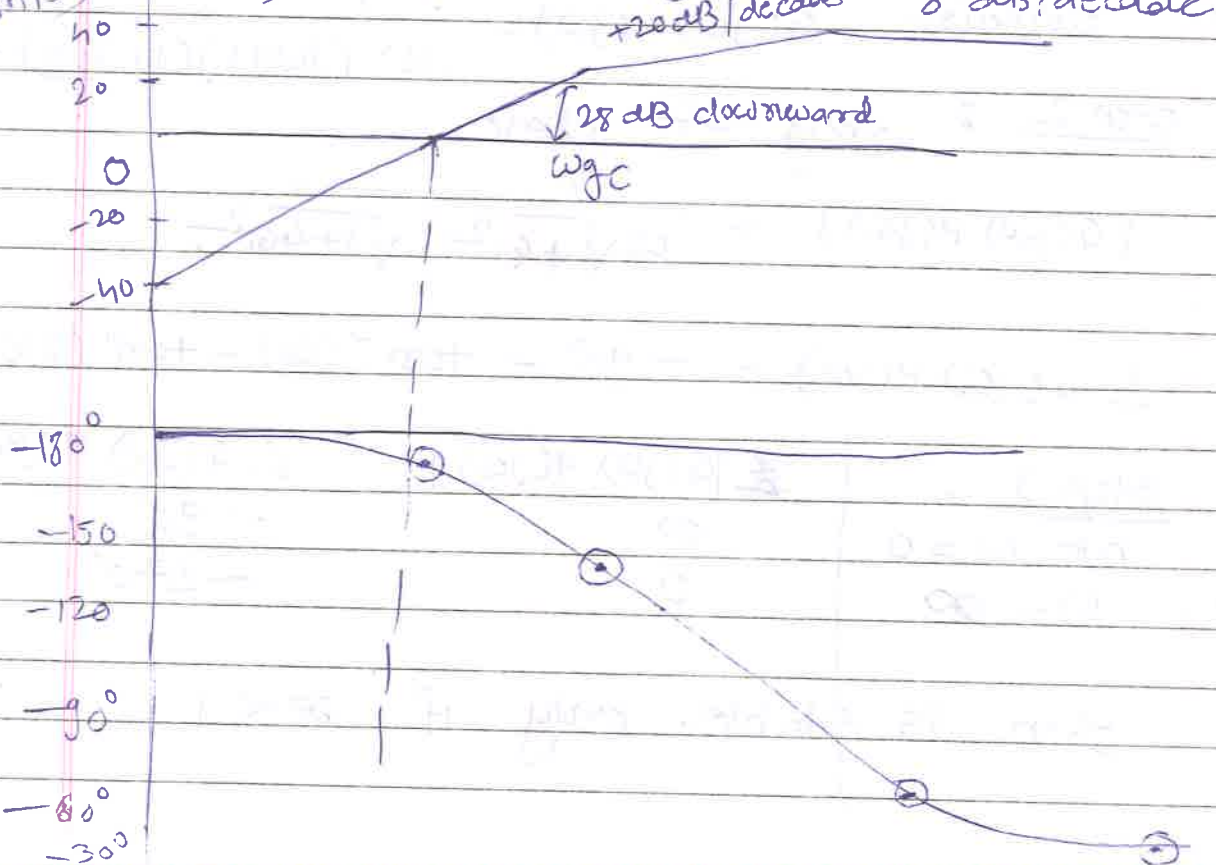
Step 8

(2 mks)

Bode

Plot.

dig.



Q.5 (A)

Controllability analysis of LTI s/m using one example - (5 mks)

Observability analysis of LTI s/m using one example - (5 mks)

(B) MRAC (model reference adaptive control) Block diag. (2 mks)
function (3 mks)

(C) $\rightarrow$ T.F. final eqⁿ

$$(2 \text{ mks}) \frac{C(s)}{R(s)} = \frac{V_2(s)}{V_1(s)} = \frac{C(s)}{R(s)} = \frac{sL}{(LCR_1 + LCR_2)s^2 + CR_1R_2 + L}$$

 $\rightarrow$ (1 mks) transformed n/w in Laplace domain

$\rightarrow$ solving $V(s)$ (1 mks)
 $V_2(s)$ (1 mks)

Q.6 (A) polar plot $G(s) = \frac{1}{s(s+1)(s+2s)}$

$\rightarrow$ (1 mks) step 1 : convert open loop T.F. to freq domain. $G(j\omega)H(j\omega) = \frac{1}{j\omega(j\omega+1)(1+2j\omega)}$

step 2 : mag & phase

(2 mks) $|G(j\omega)H(j\omega)| = \frac{1}{\omega\sqrt{1+\omega^2} \cdot \sqrt{1+4\omega^2}}$

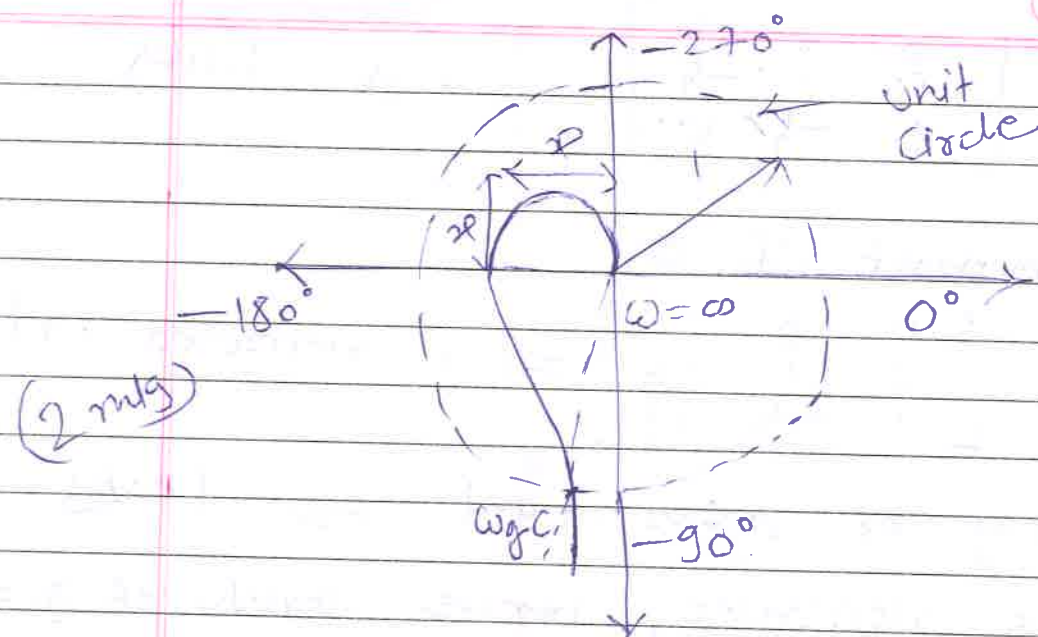
$$\angle G(j\omega)H(j\omega) = -90^\circ - \tan^{-1}(\omega) - \tan^{-1}(2\omega)$$

(2 mks)

step 3 :	$ G(j\omega)H(j\omega) $	$\angle G(j\omega)H(j\omega)$
at $\omega = 0$	∞	-90°
$\omega = \infty$	0	-270°

s/m is stable only if $\alpha < 1$

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$$\omega = 0.7071 \text{ rad/sec} \rightarrow (1 \text{ mks})$$

$$\text{So, } \omega_{pc} = 0.7071$$

put ω_{pc} in mag. condⁿ.

$$\begin{aligned} |G(j\omega) H(j\omega)| &= \frac{1}{\omega \sqrt{1+\omega^2} \cdot \sqrt{1+4\omega^2}} \\ &= 0.667 \end{aligned} \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} 2 \text{ mks}$$

$X < 1$, sys is stable

Q. 6 B]

sys is completely observable if & only if the rank of the composite matrix Q_0 is n .

$$Q_0 = [C^T : A^T C^T : \dots : (A^T)^{n-1} C^T] \rightarrow 1 \text{ mks}$$

$$\text{find } A^T \rightarrow 1 \text{ mks}$$

$$C^T \rightarrow 1 \text{ mks}$$

$$n=3$$

$$A^T C^T = \begin{bmatrix} 0 \\ 1 \\ -4 \end{bmatrix} \rightarrow 1 \text{ mks}$$

$$(A^T)^2 C^T = \begin{bmatrix} 1 \\ -1 \\ 13 \end{bmatrix} \rightarrow 1 \text{ mks}$$

$$Q_0 = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & -4 \\ 1 & -4 & 13 \end{bmatrix}$$

→ 1 mky

→ determinant of Q_0

$$\begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & -4 \\ 1 & -4 & 13 \end{bmatrix} = 1 = \text{nonzero} \rightarrow 1 \text{ mky}$$

State property of determinant → 1 mky

(1 mky) → Q_0 is nonzero, hence rank of $Q_0 = n = 3$

Q_0 is completely observable → 1 mky