

BITS, PILANI – DUBAI CAMPUS
SECOND SEMESTER 2012 – 2013
EEE/INSTR/ ECE F242 CONTROL SYSTEMS
COMPREHENSIVE EXAMINATION (CLOSED BOOK)

MAXIMUM MARKS: 80
DATE: 05.06.13 Wednesday AN

WEIGHTAGE: 40%
DURATION: 3 HOURS

NOTE: Answer Part A and Part B in separate answer sheets.

- Answer all the questions sequentially
- All the symbols and words carry their usual meanings, unless otherwise stated.
- Write your ID No. on all graph sheets.
- If a question is answered twice and not cancelled, only the first attempt will be evaluated.
- Show calculations stepwise.
- Sketches/ diagrams are to be complete in all respects.

PART A

[$4 \times 10 = 40M$]

1. The parameters of a mechanical system shown in Figure 1 are $M = 100\text{Kg}$; $B = 1000\text{N/m/sec}$; $K = 10000\text{N/m}$. A step force of 100 Newton is applied to the mass at $t=0$. From the physical parameters of the system, obtain the transfer function, damping ratio (ξ), undamped natural frequency (ω_n) and damped frequency of oscillation (ω_d). Also obtain the response for the given input. [10M]

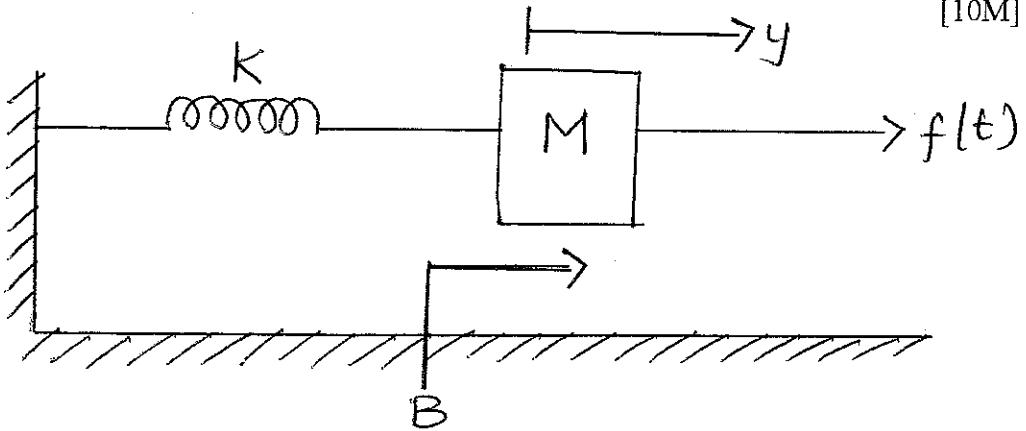


FIGURE 1

2. The open loop transfer function of a unity feedback system is $G(s) = \frac{4}{s(s+1)}$.

Determine the nature of the closed loop system for an unit step input. Also determine the rise time, peak time, peak overshoot and settling times for 2% & 5% tolerance band. [10M]

PART B

5. Draw the Bode plot (in the graph sheet provided) for the open loop transfer function

$$G(s) = \frac{2500}{s(s+5)(s+50)}$$

and determine the following.

- 5A) Gain cross over frequency
5C) Gain margin

- (5B) Phase cross over frequency
(5D) Phase margin

Assume Lower frequency = 1 rad/sec; Higher frequency = 100 rad/sec [15M]

6. The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{1}{s(1+0.2s)(1+0.05s)}$$

Draw the polar graph (in the graph sheet) and determine the frequency at which $|G(j\omega)|=1$ and the corresponding phase angle.

Assume the frequencies to be 0.6, 0.8, 1, 2, 3, 4, 5, 20 rad/sec and a scale of 1 circle = 0.05 magnitude as specified in the graph sheet provided. [10M]

7. For the system shown in Figure 4, determine the range of values of K for the following conditions:

- 7A) The closed-loop system will remain stable
7B) The closed-loop system has two poles in the right half of s-plane

[8 M]

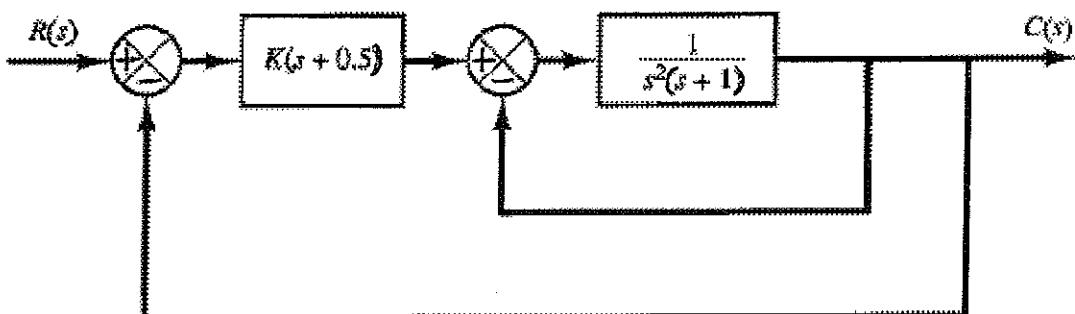


FIGURE 4

8. With respect to the Figure 5, derive the transfer function of the field-controlled DC motor in terms of motor constants.

$$i_a = \text{constant}$$

[7M]

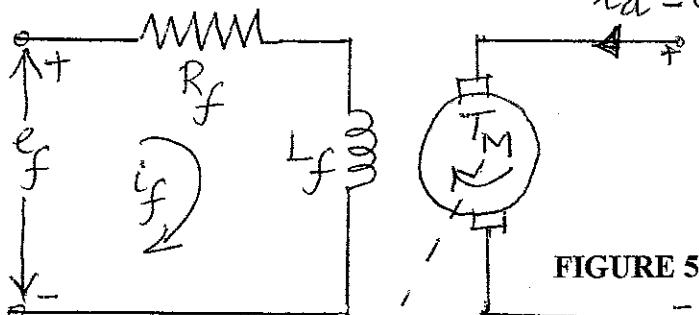
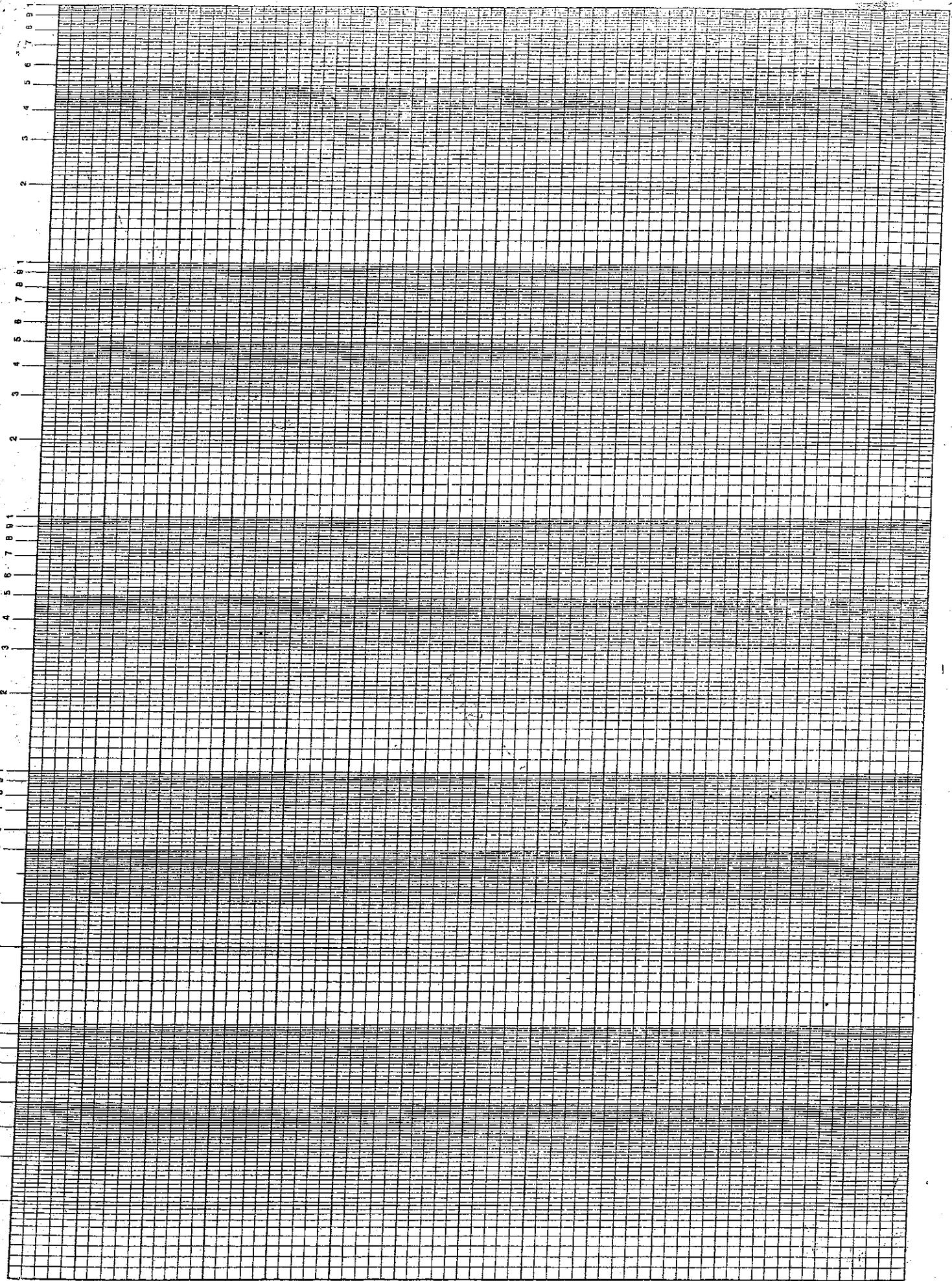
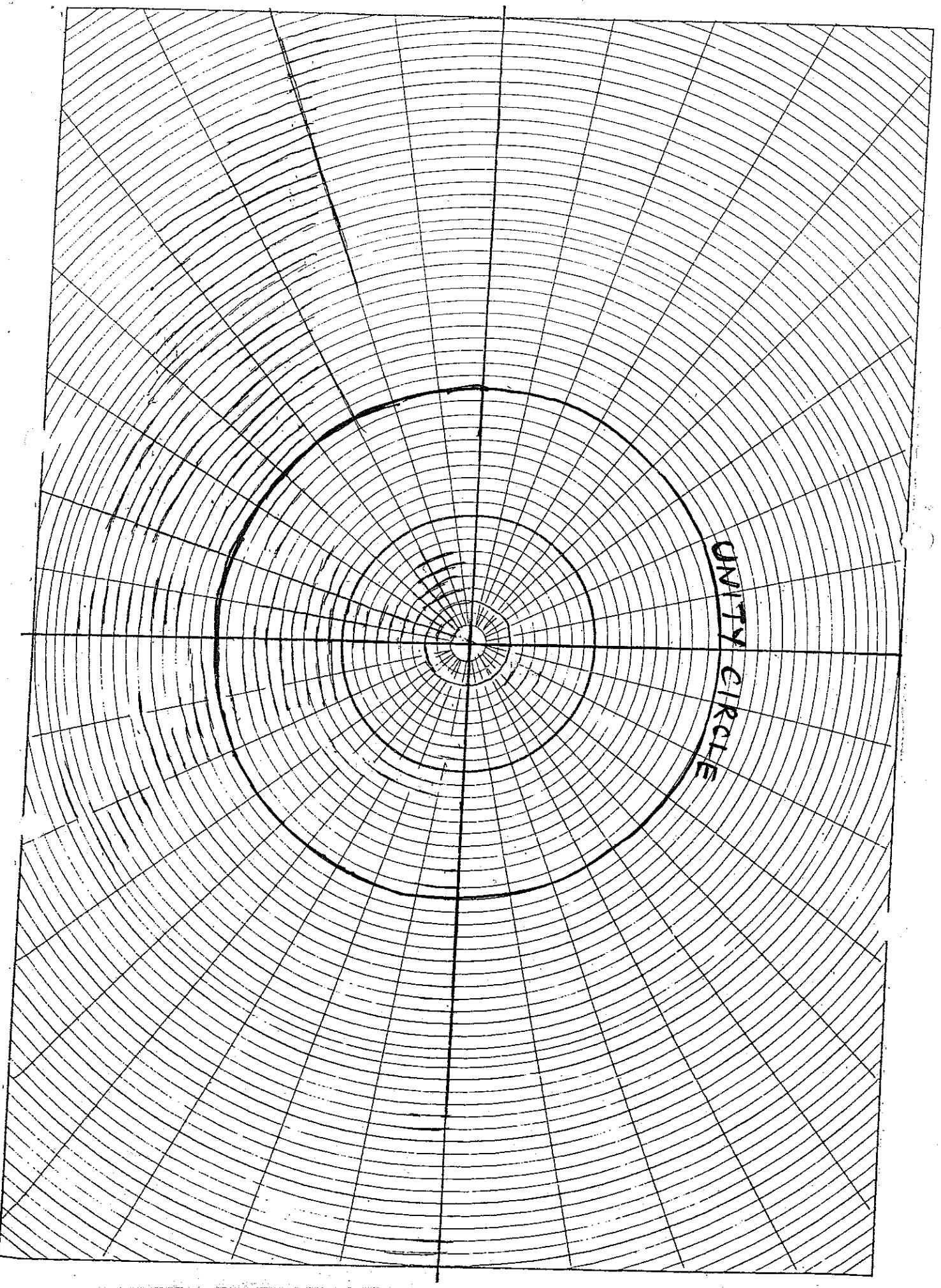


FIGURE 5



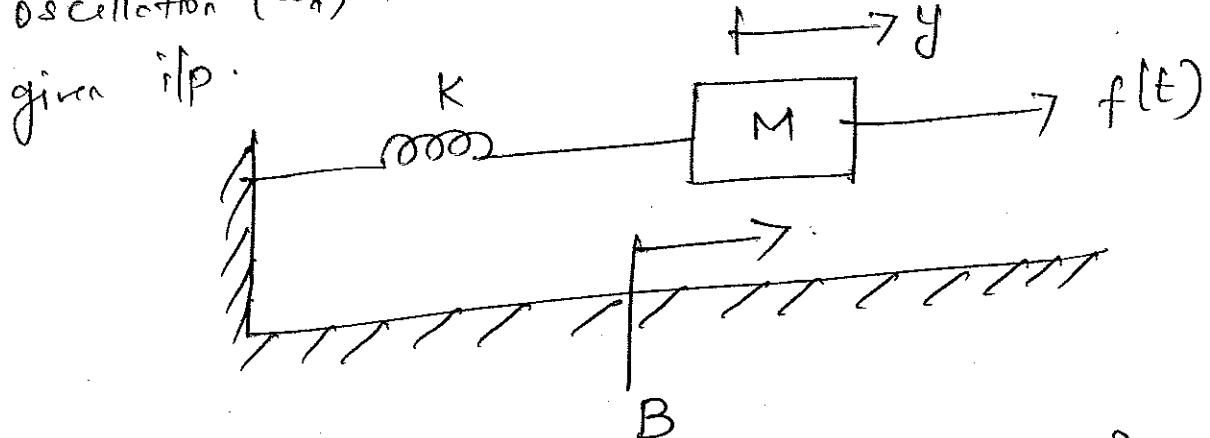


UNITY CIRCLE



CONTROL SYSTEMS - COMPRE — PART A

Q6/18: 1. The parameters of a mechanical system
 EEE F242 of figure 2 are $M = 100 \text{ kg}$; $B = 1000 \text{ N/m/sec}$.
 The physical parameters of the system, obtain the
 physical parameters of the system, obtain the
 transfer function, damping ratio (ξ), undamped
 natural frequency (ω_n) and damped frequency &
 oscillation (ω_d). Also obtain the response $y(t)$
 given i/p.



$$f(t) = \frac{M \frac{d^2 y(t)}{dt^2}}{dt} + B \frac{dy(t)}{dt} + k y(t)$$

$$F(s) = M s^2 y(s) + B s y(s) + \frac{k y(s)}{2M}$$

$$\frac{y(s)}{F(s)} = \frac{1}{100s^2 + 100s + 10000}$$

$$= \frac{0.01}{s^2 + 10s + 100}$$

By comparing; $\omega_n^2 = 100$; $2 \xi \omega_n = 10$

$\omega_n = 10 \text{ rad/s}$	$\xi = 0.5$
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For step I/P of 100 Newton,

$$R(s) = 100/s$$

$$Y(s) = \frac{100 \times 0.01}{s(s^2 + 10s + 100)}$$

$$= 0.01 \left[\frac{100}{s(s^2 + 10s + 100)} \right] \xrightarrow{2M}$$

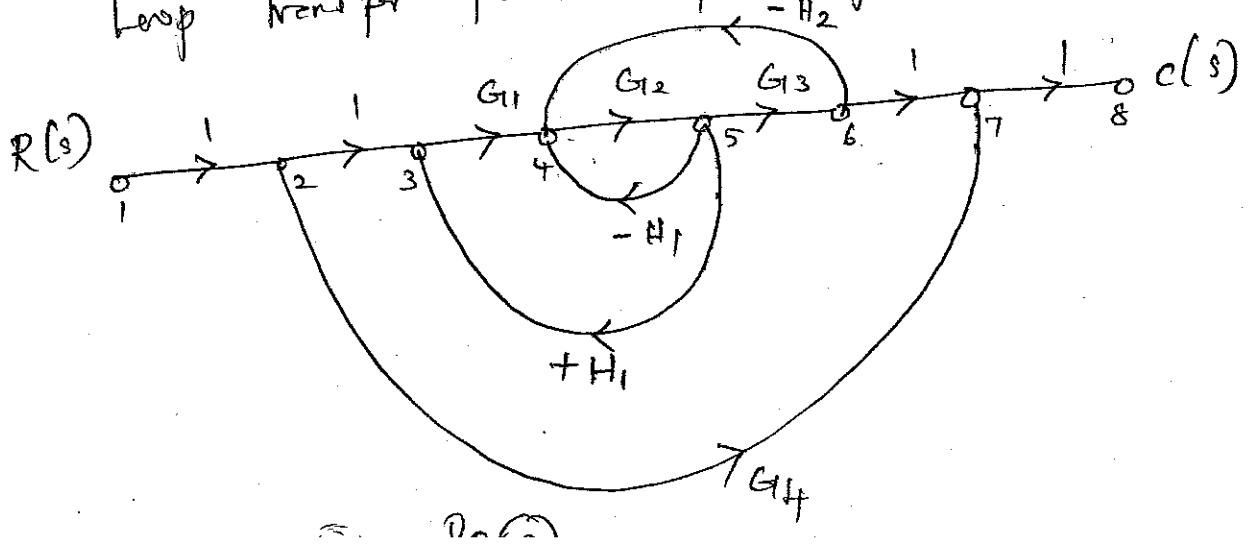
$$y(t) = 0.01 \left[1 - \frac{e^{-\xi \omega_n t}}{\sqrt{1-\xi^2}} \sin(\omega_n t + \phi) \right]$$

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

$$y(t) = 0.01 \left[1 - \frac{2}{\sqrt{3}} e^{-5t} \sin(8.66t + \pi/3) \right]$$

$$= 0.01 \left[1 - 1.156 e^{-5t} \sin(8.66t + 1.046) \right] \xrightarrow{2M}$$

4. Using Mason's gain formula, find the closed loop transfer function of a system shown in fig 3. (10m)



I Forward paths & gains:

$$P_1 = 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 = G_1 \ G_2 \ G_3 \quad] \quad 1M$$

$$P_2 = 1 \ 2 \ 7 \ 8 = G_4 \quad]$$

II Indirect loop gains:

$$P_{11} = 4 \ 5 \ 4 = -G_2 H_1 \quad] \quad 2M$$

$$P_{21} = 3 \ 4 \ 5 \ 3 = +G_1 \ G_2 H_1 \quad]$$

$$P_{31} = 4 \ 5 \ 6 \ 4 = -G_2 G_3 H_2 \quad]$$

III Gain product of two non-touching loops

NIL

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

$$= 1 - (-G_2 H_1 + G_1 G_2 H_1) - G_2 G_3 H_2$$

$$\Delta = 1 + G_2 H_1 - G_1 G_2 H_1 + G_2 G_3 H_2 \quad] \quad 1M$$

$$\Delta_K; K = 2$$

$$\Delta_1 = 1$$

$$\Delta_2 = 1 - (P_{11} + P_{21} + P_{31})$$

$$= 1 + G_2 H_1 - G_1 G_2 H_1 + G_2 G_3 H_2 \quad] \quad 2M$$

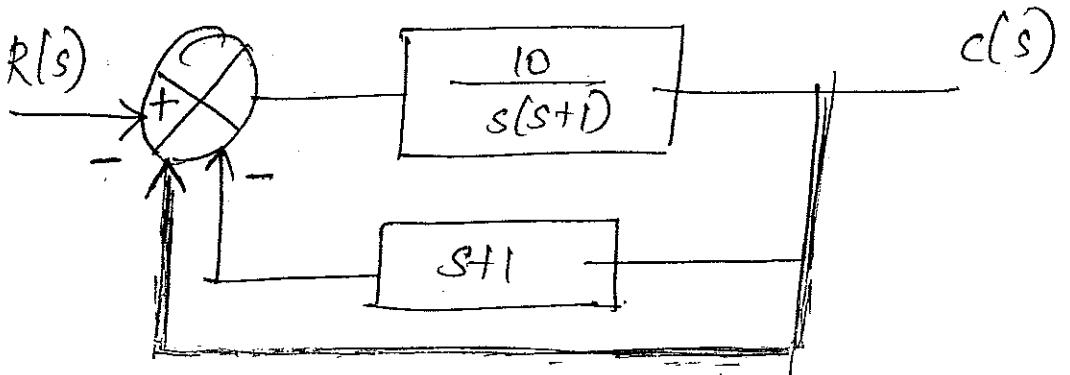
$$TF = \frac{P_1 \Delta_1 + P_2 \Delta_2}{\Delta}$$

$$= G_1 G_2 G_3 + G_4 (1 + G_2 H_1 - G_1 G_2 H_1 + G_2 G_3 H_2)$$

$$1 + G_2 H_1 - G_1 G_2 H_1 + G_2 G_3 H_2$$

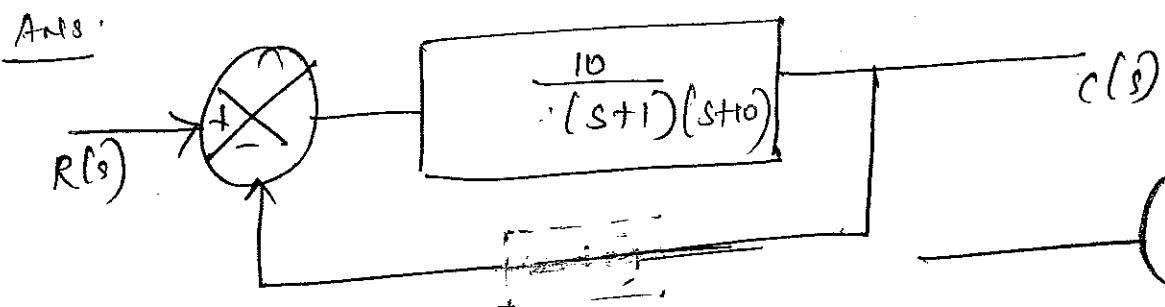
3M

3. A. For the system shown in Fig 1.2 (1m)



a. Find K_p , K_r , K_a .

b. Find the steady state error for an input (i) $5u(t)$, (ii) $5tu(t)$, (iii) $5t^2u(t)$



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

$$H(s) = 1$$

a. $K_p = \lim_{s \rightarrow 0} G(s) = \lim_{s \rightarrow 0} \frac{10}{(s+1)(s+10)}$

$\boxed{K_p = 1}$ (1m)

$$s G(s) = \lim_{s \rightarrow 0} s G(s) = 0$$

$$K_r = \lim_{s \rightarrow 0} s G(s) = \boxed{K_r = 0} \quad (1m)$$

(Part A)

$$K_a = \lim_{s \rightarrow 0} s^2 G(s) = 0$$

$$\boxed{K_a = 0} \quad \text{(1m)}$$

(b) steady state error

(i) to I/P $\propto u(t)$

$$R(s) = 5/s$$

$$e_{ss} = \lim_{s \rightarrow 0} \frac{s \cdot R(s)}{1 + G(s) H(s)}$$

$$\lim_{s \rightarrow 0} \frac{s \cdot \frac{5}{s}}{1 + \frac{10}{(s+1)(s+10)}} \times 1 = 5 \left(\frac{1}{2}\right) = 2.5$$

$$\boxed{e_{ss} = 2.5} \quad \text{(2m)}$$

(ii) I/P $\propto t u(t) \Rightarrow R(s) = 5/s^2$

$$e_{ss} = \lim_{s \rightarrow 0} \frac{s \left(\frac{5}{s^2}\right)}{1 + \frac{10}{(s+1)(s+10)}} \times 1$$

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

(iii) I/P $\propto t^2 u(t) \Rightarrow R(s) = 10/s^3$

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

$$(2) \quad G(s) = \frac{4}{s(s+1)}$$

$$\frac{C(s)}{R(s)} = \frac{\frac{4}{s(s+1)}}{1 + \frac{4}{s(s+1)}} = \frac{4}{s^2 + s + 4} \quad (1M)$$

Comp $\omega_n^2 = 4$; $2\zeta\omega_n = 1$

$\omega_n = 2$; $\zeta = 0.25$

underdamped system

1M

1. $\omega_n = 2$; $\zeta = 0.25$

1M

2. $\omega_d = \omega_n \sqrt{1 - \zeta^2} = 1.936 \text{ rad/sec}$

$$[\phi = \tan^{-1} \frac{\sqrt{1 - \zeta^2}}{\zeta}]$$

3. $\phi = 1.310 \text{ rad}$

$$[\phi = \frac{\tan^{-1} \sqrt{1 - \zeta^2}}{\zeta}] \quad 1M$$

4. $t_r = \frac{\pi - \phi}{\omega_d} = 0.945 \text{ sec.}$ 1M

5. $t_p = \frac{\pi}{\omega_d} = 1.622 \text{ sec.}$ 1M

6. $M_p = 0.4326$

$$[M_p = 0.4326] \quad 1M$$

7. $M_p = 43.26$

7. $t_s \text{ for } \frac{2}{5} M_p = \frac{8}{6} \text{ sec}$

$$[t_s = \frac{4}{\zeta\omega_n}] \quad 1M$$

$$[t_s = \frac{3}{3}\zeta\omega_n]$$

1M

Nature of the system $\zeta = 0.25$

$\zeta < 1$ so underdamped system.

1M

Perfect

m

(5)

$$G(s) = \frac{2500}{s(s+5)(s+50)}$$

Part B

Converting to time constant form

$$G(s) = \frac{10}{s(1+0.2s)(1+0.02s)}$$

$$G(j\omega) = \frac{10}{j\omega(1+j0.2\omega)(1+j0.02\omega)}$$

Magnitude plotcorner frequencies $\omega_{c1} = 5 \text{ rad/sec}$ $\omega_{c2} = 50 \text{ rad/sec}$

Term	refreq	Slope (db/dec)	Change in Slope (db)
$\frac{10}{j\omega}$	-	-20	-
$\frac{1}{1+j0.2\omega}$	$\omega_{c1} = 5$	-20	$-20 - 20 = -40$
$\frac{1}{1+j0.02\omega}$	$\omega_{c2} = 50$	-20	$-40 - 20 = -60$

$$\omega_e = 1 \text{ rad/sec}$$

$$\omega_h = 100 \text{ rad/sec}$$

[2m]

$$A = |G(j\omega)|_{\omega=\omega_e} = 20 \log \left| \frac{10}{j\omega} \right| = 20 \text{ db}$$

$$A \text{ at } \omega = \omega_{c1} = 20 \log \left| \frac{10}{j\omega} \right| = 6.02 \text{ db}$$

[4m]

$$A \text{ at } \omega = \omega_{c2} = \left(-40 \times \log \frac{50}{5} \right) + 6 = -34 \text{ db}$$

$$A \text{ at } \omega = \omega_h = \left(-60 \times \log \frac{100}{50} \right) + (-34) = -52 \text{ db}$$

Phase Plot $\phi = -90^\circ - \tan^{-1}(0.2\omega) - \tan^{-1}(0.02\omega)$ [1m]

$\omega \text{ rad/sec}$	$\phi \text{ (deg)}$
1	-103°
5	-140°
10	-165°
50	-220°
100	-210°

$$\omega_{gc} = 6.22 \text{ rad/sec}$$

$$\omega_{pc} = 15.88 \text{ rad/sec}$$

$$G_M = 14.82 \text{ db}$$

$$\phi_m = 31.72^\circ$$

[4m]

Graph - [2m]

(6)

$$G(s) = \frac{1}{s(1+0.2s)(1+0.05s)}$$

$$G(j\omega) = \frac{1}{j\omega(1+j0.2\omega)(1+j0.05\omega)}$$

$$\omega_{c1} = \frac{1}{0.2} = 5 \text{ rad/sec} \quad \omega_{c2} = \frac{1}{0.05} = 20 \text{ rad/sec}$$

$$|G(j\omega)| = \frac{1}{\omega \sqrt{1+(0.04\omega)^2} \sqrt{1+(0.05\omega)^2}}$$

$$\angle G(j\omega) = -90^\circ - \tan^{-1}(0.2\omega) - \tan^{-1}(0.05\omega) \quad [1m]$$

ω (rad/sec)	0.6	0.8	1	2	3	4	5	20	-
$ G(j\omega) $	1.65	1.23	1.0	0.5	0.3	0.2	0.14	0.0085	
$\angle G(j\omega)$ deg	-98.5	-101	-104	-117.5	-120	-140	-150	-210	[3m]

Graph — [3m]

$$|G(j\omega)| = \frac{1}{\omega \sqrt{1+0.04\omega^2} \sqrt{1+2.5 \times 10^{-3}\omega^2}} \quad [1m]$$

Frequency at which $|G(j\omega)| = 1$ is $\omega = 1 \text{ rad/sec}$ — [1m]The corresponding angle = -104° . — [1m]

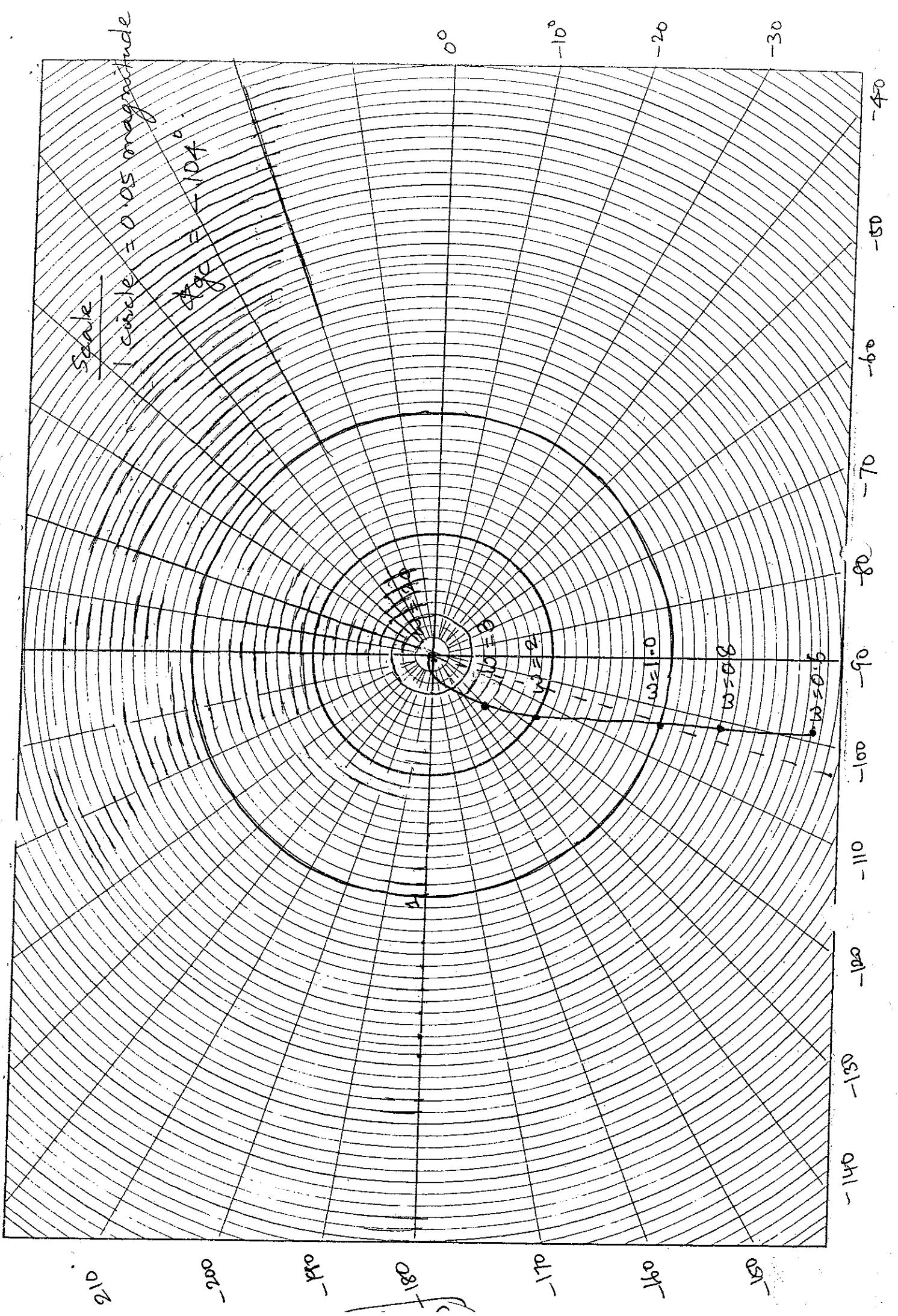
7) Charac egn $s^3 + s^2 + ks + (0.5k+1) = 0 \quad [2m]$

s^3	1	K	$0.5K+1 > 0$	$0.5K-1 > 0$
s^2	1	$0.5K+1$	$K > 2$	$K > 2$
s^1	$0.5K-1$	0		
s^0	$0.5K+1$	0		

A) Closed loop system is stable for $K > 2$ — [2m]B) has 2 poles for $-2 < K < 2$

2 sign changes in I column of Routh array

[2m] — [2m]



8. $i_a = \text{constant}$

$$T_m \propto i_a \phi = k_i k_f \text{ if } i_a = k_T' \text{ if }$$

$$e_f = L_f \frac{di_f}{dt} + R_f i_f$$

$$T_m = k_T' i_f = J \frac{d^2\theta}{dt^2} + f \frac{d\theta}{dt}$$

} — [2m]

Taking LT, and from above

$$k_T' \left(\frac{E_f(s)}{sL_f + R_f} \right) = (Js^2 + fs)\theta(s)$$

$$TF = \frac{\theta(s)}{E_f(s)} = \frac{k_T'}{(sL_f + R_f)(Js^2 + fs)} — [2m]$$

$$= \frac{k_T'}{s(sL_f + R_f)(Js + f)}$$

$$= \frac{k_T'}{sR_f \left(1 + \frac{sL_f}{R_f}\right) \left(1 + \frac{Js}{f}\right) f}$$

$$= \frac{k_m}{s(1 + \zeta_f s)(1 + \zeta_{me}s)} — [3m]$$

where

$$\zeta_f = \frac{L_f}{R_f}$$

$$k_m = \frac{k_T'}{f R_f}$$

$$\zeta_{me} = \frac{J_r}{f}$$

= motor gain constant

ζ_f = time constant of field circuit

ζ_{me} = mechanical time constant

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 SECOND SEMESTER 2012 – 2013
 EEE/INSTR/ ECE F242 CONTROL SYSTEMS
 TEST 2 (OPEN BOOK)

MAXIMUM MARKS: 40
DATE: 02.05.13

WEIGHTAGE: 20%
DURATION: 50 MINUTES

- NOTE:** 1) Attempt all parts of a question sequentially.
 2) If a question is answered twice and not cancelled, only the first attempt will be evaluated.
 3) Show calculations stepwise.
 4) Sketches/ diagrams are to be complete in all respects.

1. A system is shown below;
 (i) In the absence of derivative feedback ($a=0$), find ξ (damping ratio) and ω_n (undamped natural frequency).
 (ii) Find 'a' to change ξ to 0.7
 (iii) Find % peak overshoot M_p in both cases. [14M]

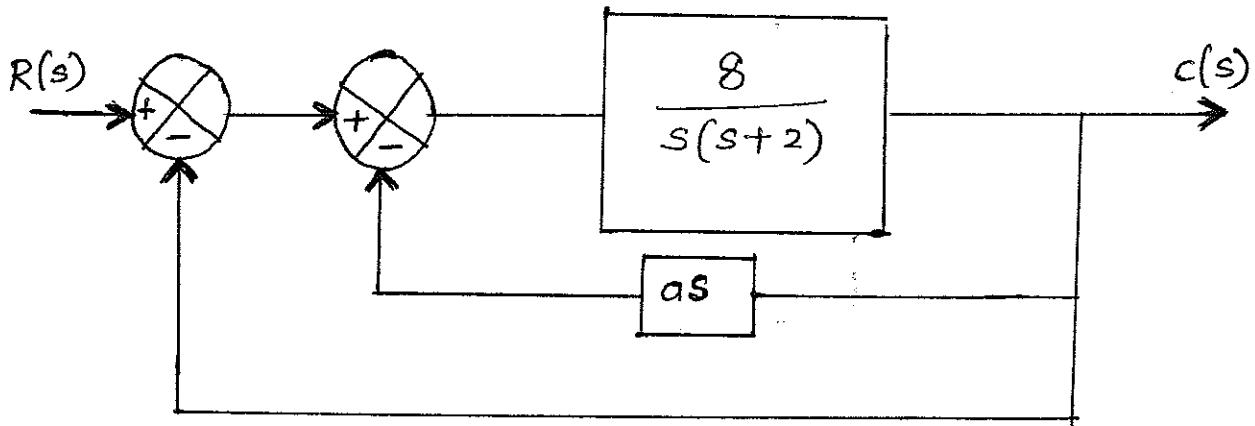


Figure 1

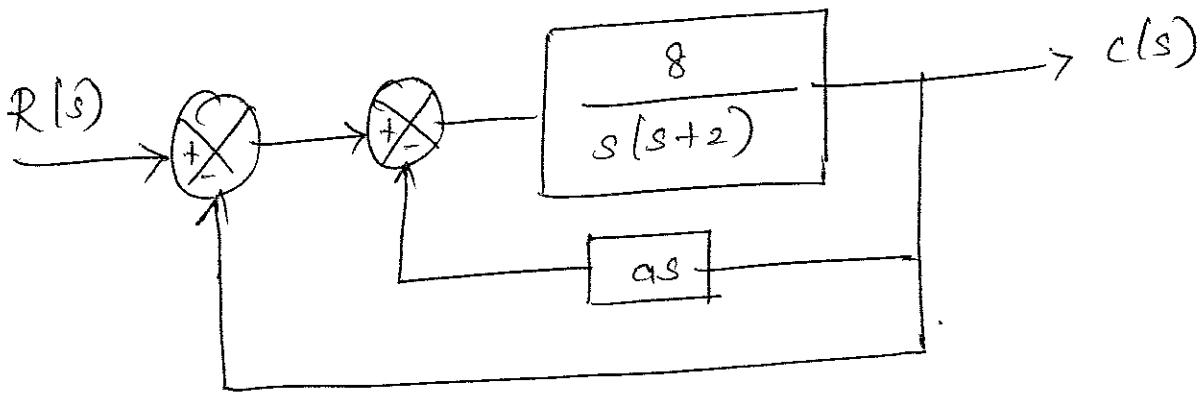
2. The forward path transfer function of a unity feedback control system is given by
 $G(s) = \left(100 + \frac{K}{s}\right) \left(\frac{1}{4s^2 + 2s}\right)$. Determine the range of value of 'K' for which the system will remain stable. [6M]

3. A unity feedback control system has an open loop transfer function $G(s) = \frac{K(s+1)}{s(s-3)}$. Draw the root locus in the graph sheet provided. Draw it to scale. Write Conclusion/Summary. [20M]

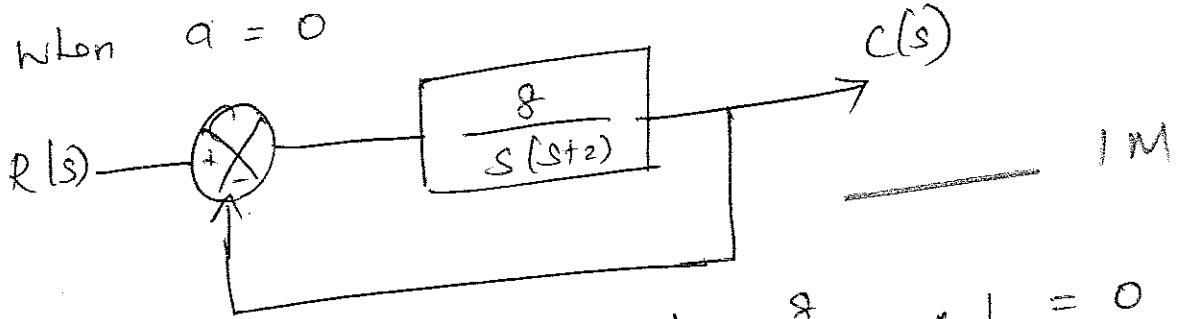
A system is shown below

14M

- In absence of derivative feedback ($a=0$)
find $\xi \& \omega_n$.
- Find a to increase ξ to 0.7
- Find M_p in both cases.



(i) When $a = 0$



$$C_{der.} \text{ eqn} = 1 + G_1 H = 1 + \frac{8}{s(s+2)} * 1 = 0$$

$$C_{der.} \text{ eqn} = s^2 + 2s + 8 = 0$$

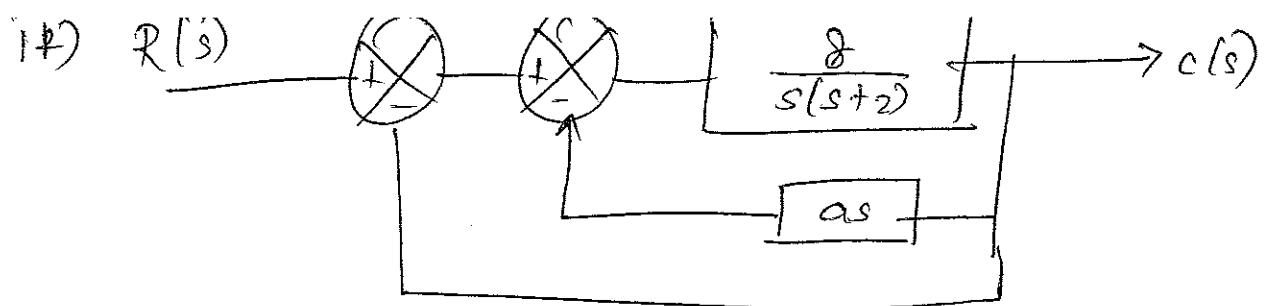
$$\text{Comparing with } s^2 + 2\xi\omega_n + \omega_n^2 = 0.$$

$$\omega_n^2 = 8 ; 2\xi\omega_n = 2$$

$$\omega_n = \sqrt{8} ; \xi\omega_n = 1$$

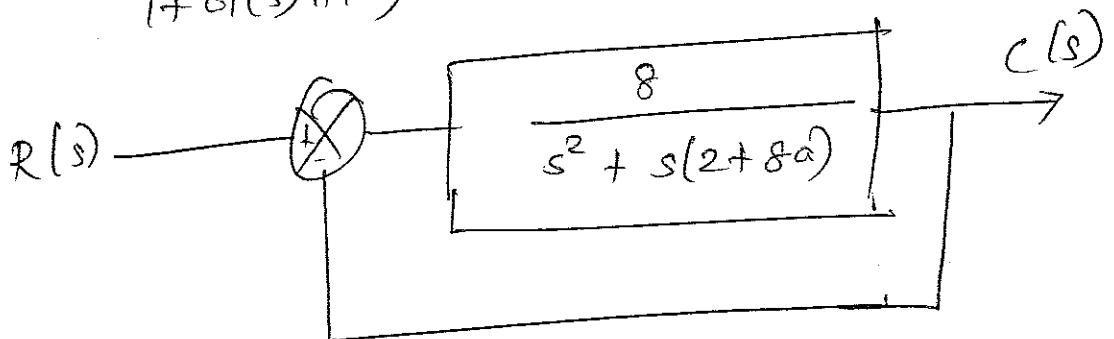
$$\omega_n = 2.82 \text{ rad/sec} ; \xi = \frac{1}{\omega_n}$$

$\omega_n = 2.82$	$\xi = 0.3535$	2M
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Reducing the inner loop,

$$\frac{G_1(s)}{1 + G_1(s)H(s)} = \frac{8}{s^2 + s(2+8a)} \quad \underline{2 M}$$



$$\text{Outer expr} = 1 + G_1(s)H(s)$$

$$= 1 + \frac{8}{s^2 + s(2+8a)} = 0.$$

$$s^2 + s(2+8a) + 8 = 0 \quad \underline{2 M}$$

$$\text{Comparing with } s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$$

$$\omega_n^2 = 8$$

$$2\zeta\omega_n = 2 + 8a$$

$$\zeta = 0.7.$$

$$\omega_n = 2.828$$

$$2 \times 0.7 \times 2.828 = 2 + 8a$$

$\omega_n = 2.828$	$a = 0.2449$
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2 M

$$\textcircled{1} \quad M_p \text{ for } a = 0 = e^{-1/11.9} \cdot$$

$$\zeta = 0.3535$$

$$M_p = 0.305$$

$$\therefore M_p \text{ for } a = 0 = 30.5 \% \quad \boxed{2M}$$

$$M_p \text{ for } a = 0.2449$$

$$M_p = 0.046$$

$$\therefore M_p \text{ for } a = 0.2449 = 4.6 \% \quad \boxed{2M}$$

(2) The forward path transfer function of a unity feedback control system is given by

$$G_1(s) = \left(100 + \frac{K}{s}\right) \left(\frac{1}{4s^2 + 2s}\right)$$

Determine the range of value of K for which the system will remain stable. $\rightarrow \boxed{6M}$

$$G_1(s) = \left(100 + \frac{K}{s}\right) \left(\frac{1}{4s^2 + 2s}\right)$$

$$= \frac{100s + K}{4s^3 + 2s^2} \quad \boxed{1M}$$

$$\text{char. eqn} = 1 + G_1(s)H(s) = 0$$

$$1 + \frac{100s + K}{4s^3 + 2s^2} = 0$$

$$C.E = 4s^3 + 2s^2 + 100s + K = 0 \quad \boxed{1M}$$

$$\begin{array}{ccc}
 S^3 & 4 & 100 \\
 S^2 & 2 & K \\
 S^1 & \frac{200 - 4K}{2} & 0 \\
 S^0 & K & \emptyset
 \end{array}
 \quad 2m$$

$K > 0$

$$\frac{200 - 4K}{2} > 0$$

$$200 - 4K > 0$$

$$200 > 4K$$

$$50 > K$$

$$\boxed{0 < K < 50} \rightarrow \text{Range of } K$$

2m

$$G(s) = \frac{K(s+1)}{s(s-3)}$$

Draw the ~~on~~ graph sheet provided.
~~to scale~~ (Draw to Scale)

Step 1
P = 2 at $s=0, 3$

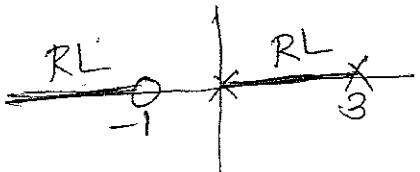
Z = 1 at $s = -1$

n = P = 2 branches of RL

No of branches terminating at $\infty = P-Z=1$ [3m]

could be 2 breakaway pts.

Step 2



[2m]

Step 3

Asymptotes $\phi = 180^\circ$.

$$\textcircled{4} \quad \text{Centroid } \sigma = \frac{(0+3)-(-1)}{1} = 4 \quad [2m]$$

$$\textcircled{5} \quad 1 + \frac{K(s+1)}{s(s-3)} = 0 \Rightarrow K = \frac{-s(s-3)}{(s+1)}$$

$$\frac{dK}{ds} = 0 \text{ yields } s^2 + 2s - 3 = 0 \Rightarrow s=1, -3 \quad [5m]$$

$$\textcircled{6} \quad \text{Charac eqn } s^2 + (K-3)s + K = 0$$

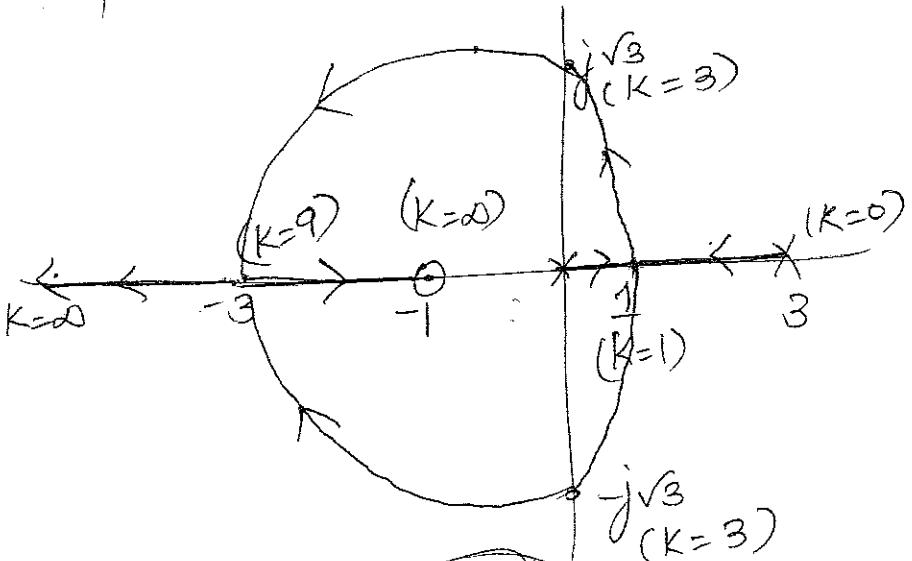
s^2	1	K
s	$K-3$	
s^0	K	

$K-3=0$
 $K=3$ for marginal stability

$$s^2 + K = s^2 + 3 = 0$$

$$s = \pm j\sqrt{3} \quad [3m]$$

7



Summary
 $0 < K < 3$

-unstable

$K=3$ marginally stable

$K > 3$ stable

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SECOND SEMESTER 2012 – 2013
EEE/INSTR/ ECE F242 CONTROL SYSTEMS
TEST 1 (CLOSED BOOK)

MAXIMUM MARKS: 50
DATE: 14.03.13

WEIGHTAGE: 25 %
DURATION: 50 MINUTES

- NOTE:**
- 1) Attempt all parts of a question sequentially.
 - 2) If a question is answered twice and not cancelled, only the first attempt will be evaluated.
 - 3) Show calculations stepwise.
 - 4) Sketches/ diagrams are to be complete in all respects.

1. Obtain $\frac{C(s)}{E(s)}$ for the system shown in Figure 1, if $N(s) = 0$

Note: $C(s)$ and $E(s)$ should be fully reduced to the form of equations with powers of s .

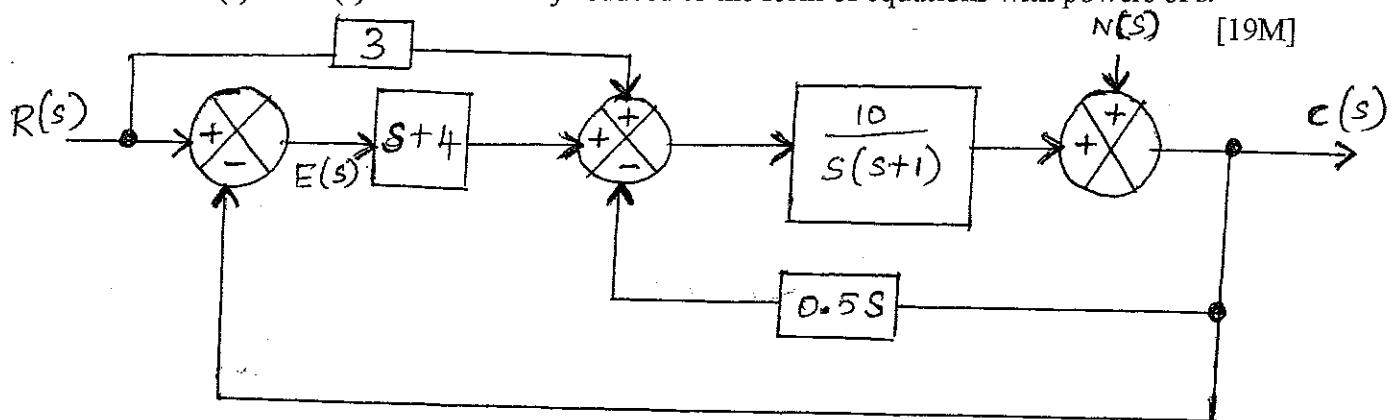


FIGURE 1

2. Write the differential equations governing the mechanical translational system shown in Figure 2. [6M]

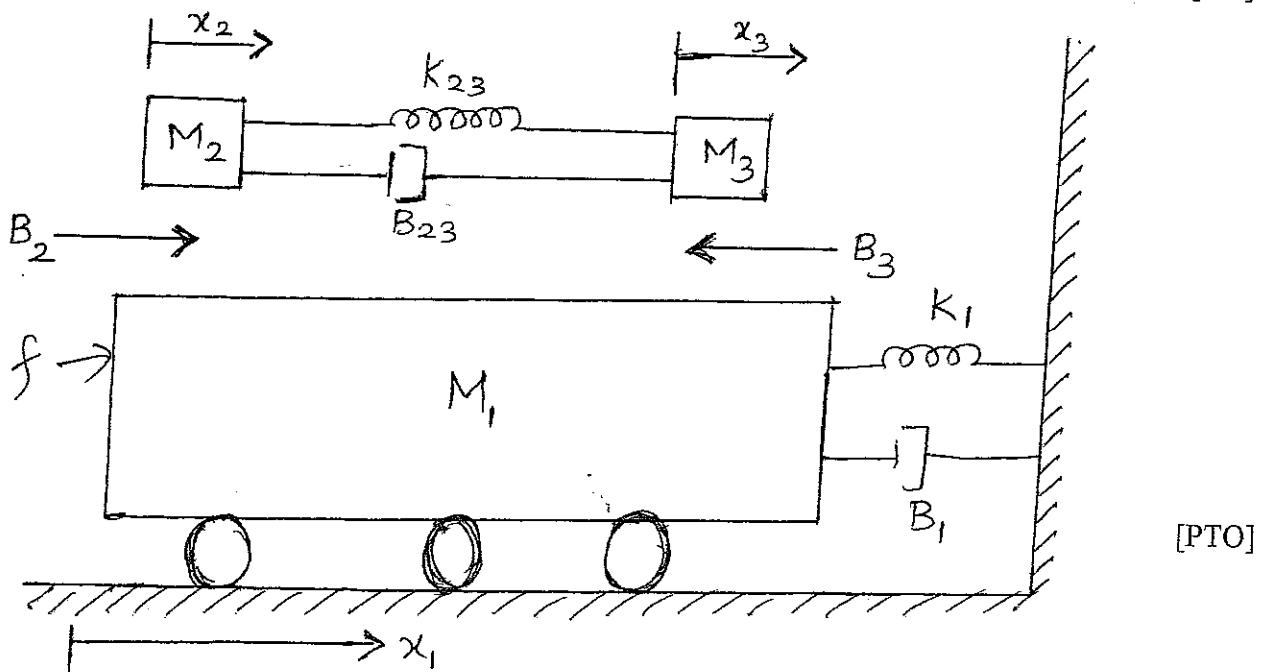
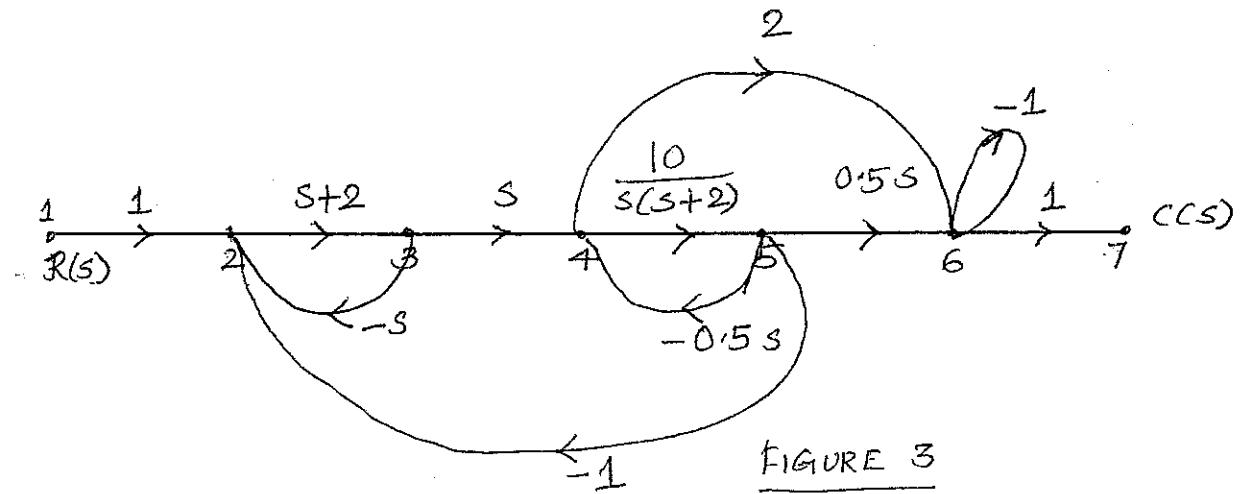


FIGURE 2

3. Apply the gain formula to the Signal Flow Graph shown in Figure 3 and find the overall transfer function $C(s) / R(s)$ [20M]

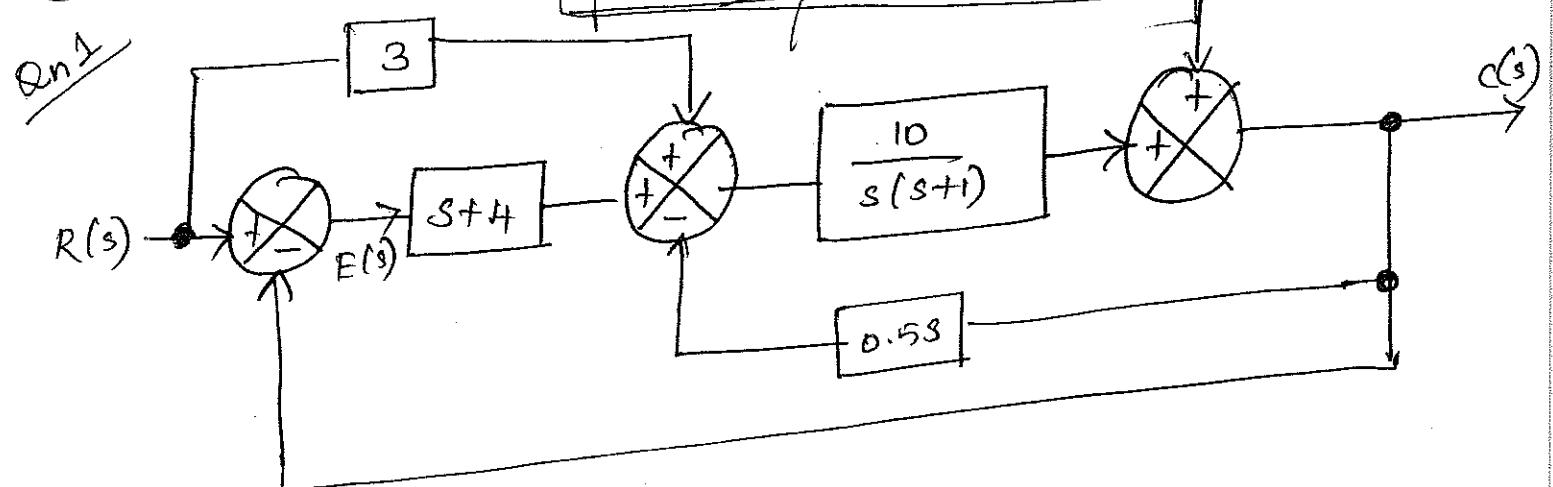
Note: $C(s)$ and $R(s)$ should be fully reduced to the form of equations with powers of s .



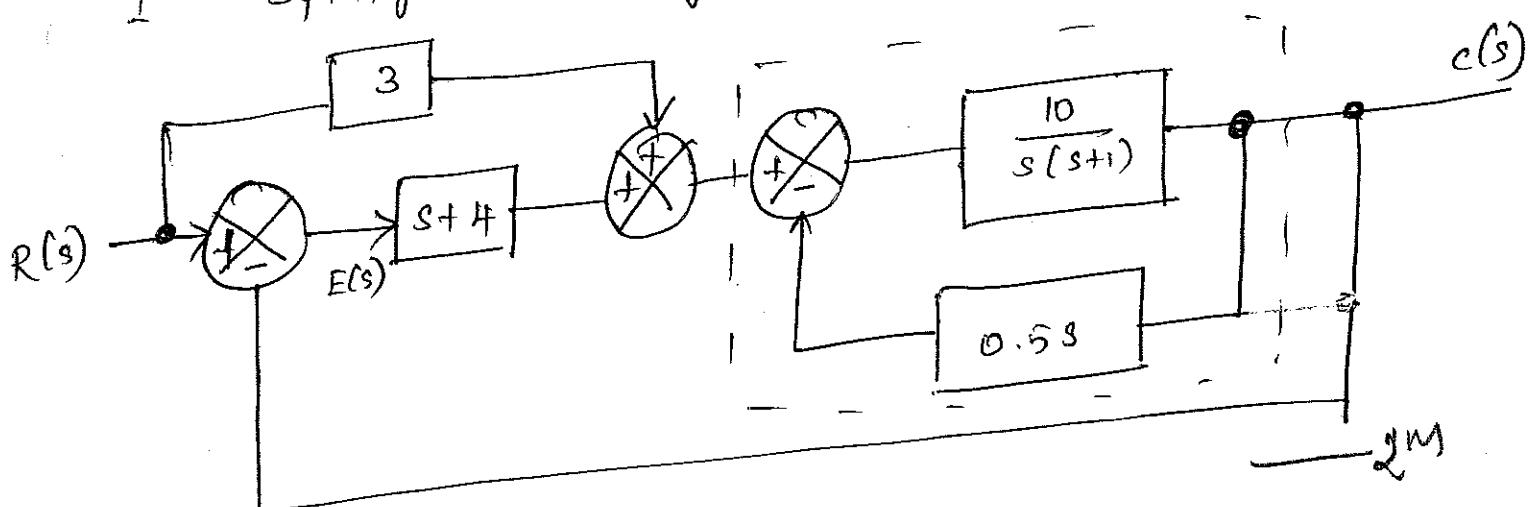
4. Tabulate the analogous quantities of a mechanical translational system with that of electrical system in Force-Current analogy. [5M]

~~complete
simpler
block~~ Obtain $\frac{c(s)}{E(s)}$ for the system shown below, if $N(s) = 0$

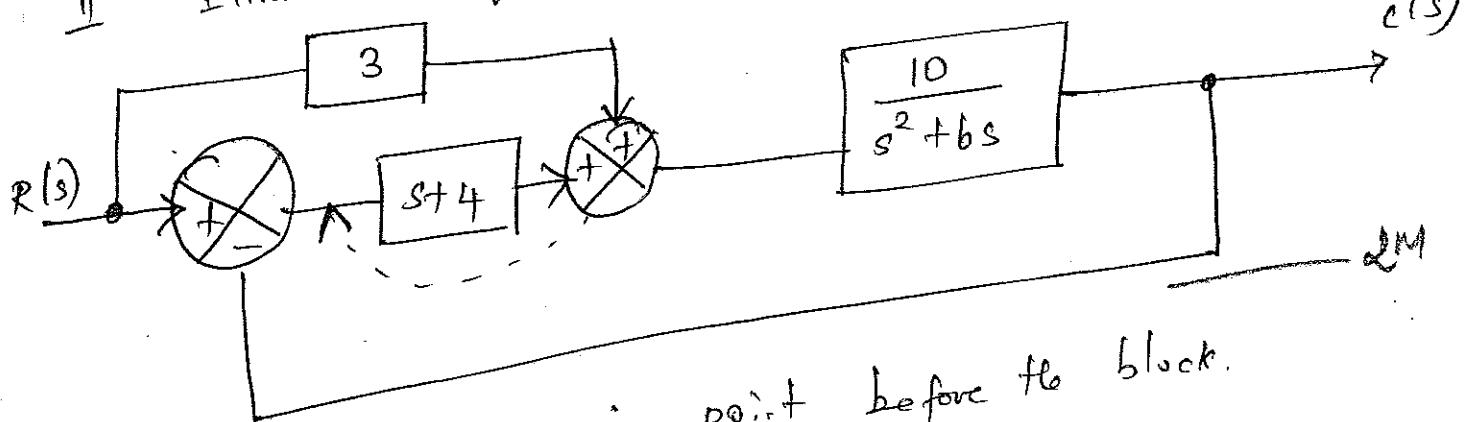
Pg 1



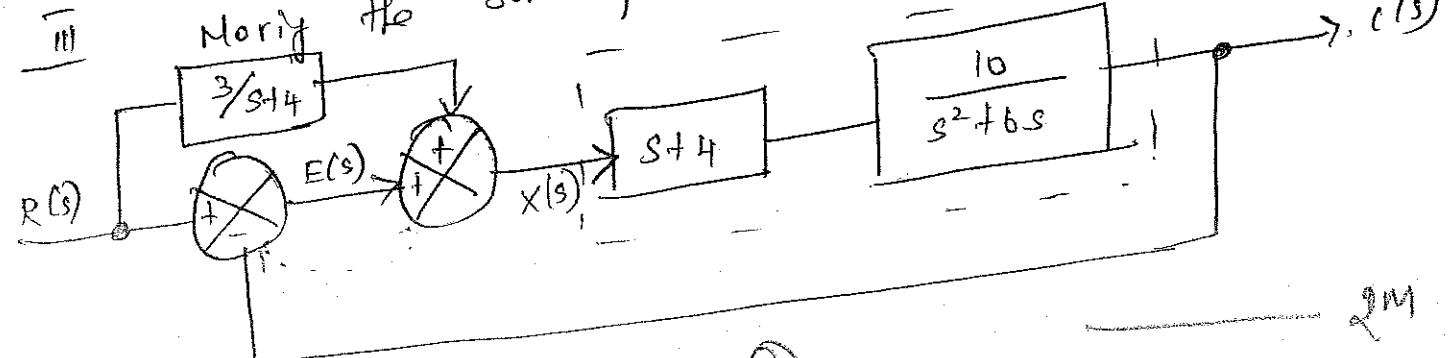
I splitting the summing point



II Elimination of feedback loop:



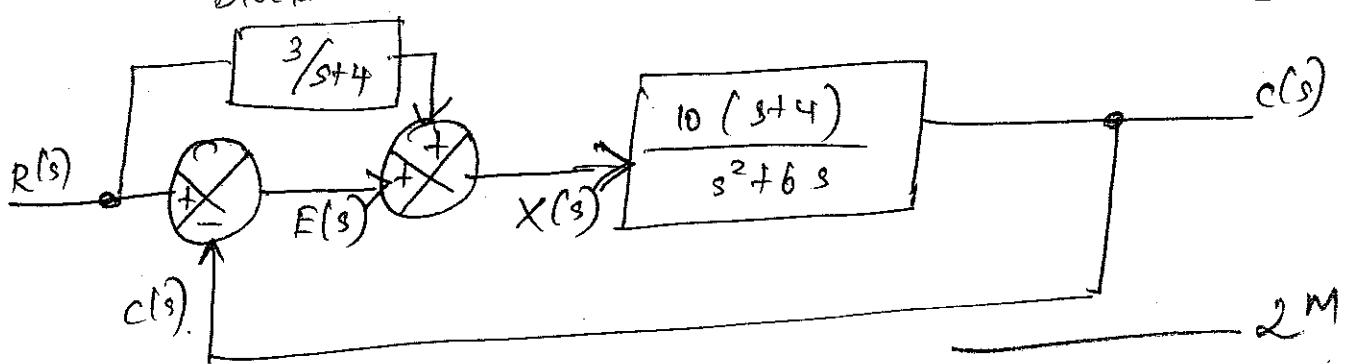
III Moving the summing point before the block.



18

Simplifying the circuit by combining the blocks in cascade

Pg 2



Assume $X(s)$

$$\text{Now; } E(s) = R(s) - c(s) \quad \text{--- } \textcircled{1} \quad \left. \begin{array}{l} \\ \end{array} \right\}$$

$$c(s) = X(s) \cdot \frac{10(s+4)}{s^2 + 6s} \quad \text{--- } \textcircled{2} \quad \left. \begin{array}{l} \\ \end{array} \right\}$$

$$X(s) = E(s) + \frac{3}{s+4} R(s) \quad \text{--- } \textcircled{3} \quad \left. \begin{array}{l} \\ \end{array} \right\} 3M$$

$$\text{From eqn } \textcircled{2} \Rightarrow X(s) = \frac{c(s)[s^2 + 6s]}{10(s+4)} \quad \text{--- } \textcircled{4} \quad \left. \begin{array}{l} \\ \end{array} \right\}$$

Sub $\textcircled{4}$ in to $\textcircled{3}$

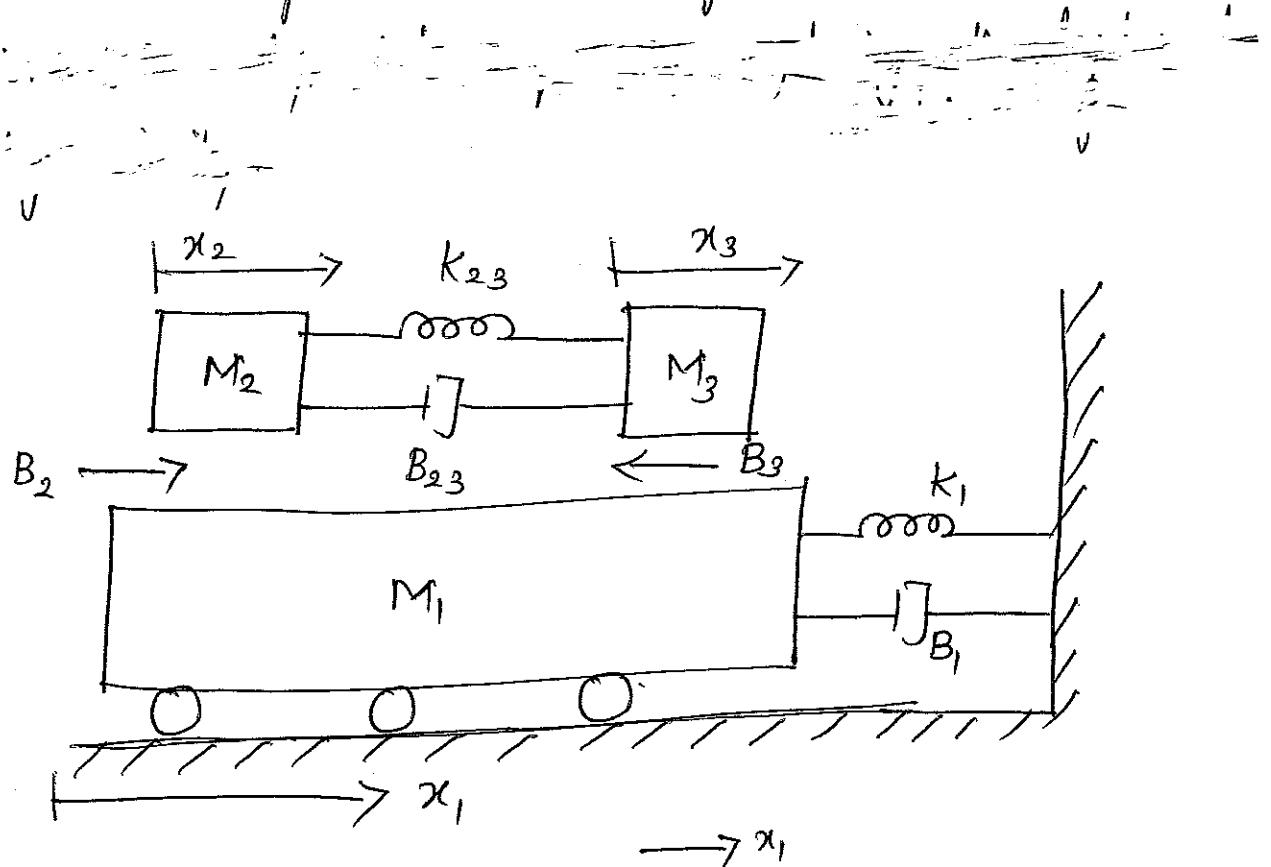
$$\frac{c(s)[s^2 + 6s]}{10(s+4)} = E(s) + \frac{3}{s+4} [E(s) + c(s)] \quad \left. \begin{array}{l} \\ \end{array} \right\} 4M$$

$$\left[\frac{s^2 + 6s}{10(s+4)} - \frac{3}{s+4} \right] c(s) = E(s) \left[1 + \frac{3}{s+4} \right]$$

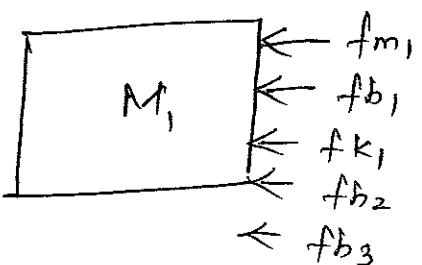
$$\left[\frac{s^2 + 6s - 30}{10(s+4)} \right] c(s) = \left[\frac{s+7}{s+4} \right] E(s)$$

$$\frac{c(s)}{r(s)} = \frac{10(s+7)}{s^2 + 6s - 30} = \frac{10s^2 + 70}{s^2 + 6s - 30} \quad \left. \begin{array}{l} \\ \end{array} \right\} 4M$$

~~Qn 2~~ Write the differential eqn's governing the mechanical translational system shown in fig 2. And also Pg 3

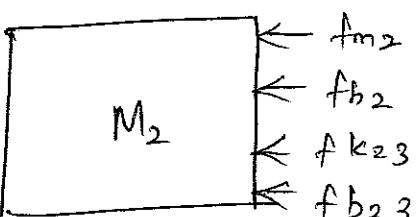


For M_1 ,



$$M_1 \frac{d^2x_1}{dt^2} + B_1 \frac{dx_1}{dt} + k_1 x_1 + B_2 \frac{d}{dt}(x_1 - x_2) + B_3 \frac{d}{dt}(x_1 - x_3) = F \quad 2M$$

For M_2



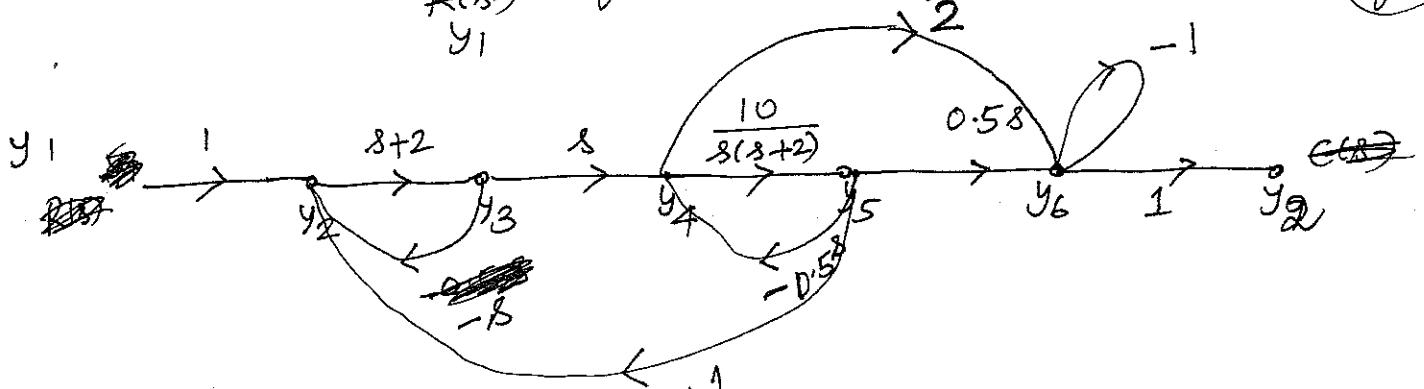
$$M_2 \frac{d^2x_2}{dt^2} + B_2 \frac{d}{dt}(x_2 - x_1) + k_{23}(x_2 - x_3) + B_{23} \frac{d}{dt}(x_2 - x_3) = \textcircled{O} \quad 2M$$

$$M_3 \frac{d^2x_3}{dt^2} + B_3 \frac{d}{dt}(x_3 - x_1) + B_{23} \frac{d}{dt}(x_3 - x_2) + k_{23}(x_3 - x_2) = 0 \quad 2M$$

(3)

~~Qn 3~~ Calculate $TF = \frac{Y_2}{Y_1}$ of the following sys -

Pg 4



I Forward path 1: $(1 2 3 4 5 6 7) \rightarrow (s+2)(s) \left(\frac{10}{s(s+2)}\right)(0.58)(1) = 58$

II Forward path 2: $(1 2 3 4 6 7) \rightarrow (s+2)(s)(2)(1) = 2s(s+2)$

III Indl. loops: $(2 3 2) \rightarrow -s(s+2)$

$$(4 5 4) \rightarrow \frac{10}{s(s+2)} (-0.58) = \cancel{-5} \frac{-5}{s+2}$$

$$(6-6) \rightarrow -1$$

$$(2 3 4 5 2) \rightarrow -10$$

2M

4M

IV Combinations of 2 non-touching loops

$$(2 3 2)(4 5 4) \rightarrow (-s)(s+2) \left(\frac{-5}{s+2}\right) \Rightarrow 58.$$

$$(4 5 4)(6-6) \rightarrow \left(\frac{-5}{s+2}\right)(-1) = \frac{5}{s+2}$$

$$(2 3 2)(6-6) \rightarrow (-s)(s+2)(-1) = s(s+2)$$

$$(2 3 4 5 2)(6-6) \rightarrow (-10)(-1) = 10$$

4m

V combination of 3 non-touching loops.

$$(2 3 2)(4 5 4)(6-6) \rightarrow (-s)(s+2) \left(\frac{-5}{s+2}\right)(-1) = -58.$$

$$\begin{aligned} \Delta &= 1 - \left\{ -s^2 - 2s - \frac{5}{s+2} - 1 - 10 \right\} + \left\{ 58 + \frac{5}{(s+2)} + s^2 + 2s + 10 \right. \\ &\quad \left. - (-58) \right\} \\ &= 1 - \left\{ -s^2 - 2s - \frac{5}{s+2} - 11 \right\} + \left\{ \cancel{-5} \frac{5}{s+2} + s^2 + 2s + 10 \right\} \\ &\quad + 58 \end{aligned}$$

$$\begin{aligned}
 \Delta &= 1 + s^2 + 2s + \frac{10}{s+2} + 11 + \cancel{\frac{5s}{s+2}} + s^2 + 7s + 10 + 58 \\
 &= (s+2 + s^3 + 2s^2 + 2s^2 + 4s + 10 + 11s + 22 + s^3 + 2s^2 \\
 &\quad + 7s^2 + 14s + 10s + 20 + 5s^2 + 10s) / (s+2) \\
 &= \frac{2s^3 + 18s^2 + 50s + 54}{s+2}
 \end{aligned}$$

$$\Delta_1 = 1; \Delta_2 = 1;$$

$$\begin{aligned}
 TF &= \frac{C(s)}{R(s)} = \frac{(5s + 2s^2 + 4s)(s+2)}{2s^3 + 18s^2 + 50s + 54} \\
 &= \frac{2s^3 + 13s^2 + 18s}{2s^3 + 18s^2 + 50s + 54}
 \end{aligned}$$

— 3m
— 2m

— 3m.

<u>Qn A</u>	<u>mech Translational System</u>	<u>Electrical System.</u>
	Force	Current
	mass	Capacitance
	Viscous friction	1/Resistance
	Spring const	1/Inductance
	Displacement	magnetic flux
	Velocity	voltage

— 5M

BITS, PILANI – DUBAI CAMPUS
 SECOND SEMESTER 2012 – 2013
 EEE/INSTR/ ECE F242 CONTROL SYSTEMS *1 year*
 QUIZ 1 (CLOSED BOOK)

MAXIMUM MARKS: 16
DATE: 28.02.13

SET A

WEIGHTAGE: 8 %
DURATION: 20 MINUTES

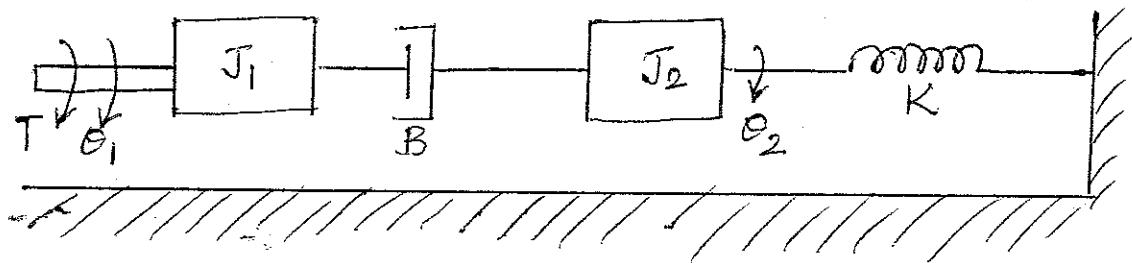
Name:

Id No.:

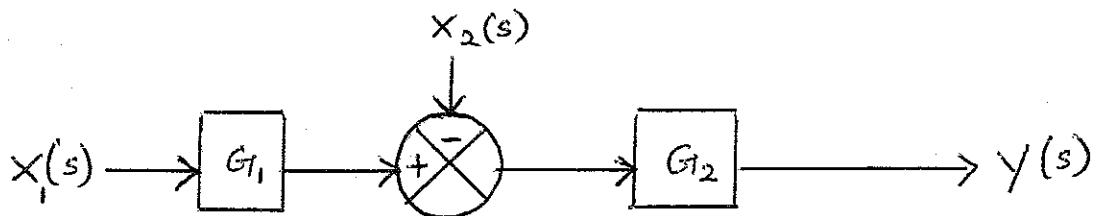
Section: RGB /RSL

1. Write the differential equations governing the mechanical system shown below. [4M]

Ans: _____



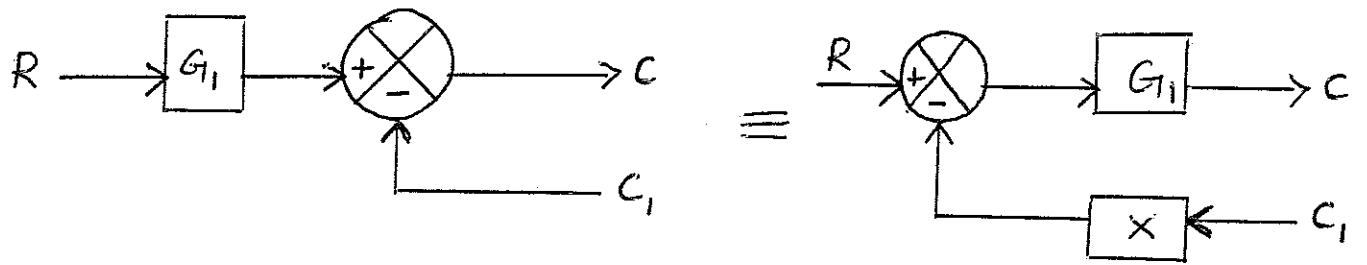
2. Find the output for the block diagram shown below. [2M]



$$Y(s) = \underline{\hspace{10cm}}$$

3. What is the value of 'X' for which the two blocks are equal?

[3M]



$$X = \underline{\hspace{10cm}}$$

4. For the transient response analysis of Single-Input-Single-Output linear time-invariant systems, _____ representation is useful while a Multiple-Input-Multiple-Output system can be conveniently represented using the vector-matrix notation. [1M]

5. The error detector in a basic control loop compares _____ signal with the signal obtained through _____ elements. [2M]

6. The super position principle is applicable to _____ systems. [1M]

7. Mention the analogous quantities for the following for force - voltage analog? [2M]

displacement - _____; velocity - _____

8. The ratio of θ_1 / θ_2 is equal to the ratio of _____ (with respect to number of teeth) in gear train. [1M]

SET A

BITS, PILANI – DUBAI CAMPUS
SECOND SEMESTER 2012 – 2013
EEE/INSTR/ ECE F242 CONTROL SYSTEMS
QUIZ 1 (CLOSED BOOK)

MAXIMUM MARKS: 16
DATE: 28.02.13

SET B

WEIGHTAGE: 8 %
DURATION: 20 MINUTES

Name:	Id No:	Section: RGB /RSL
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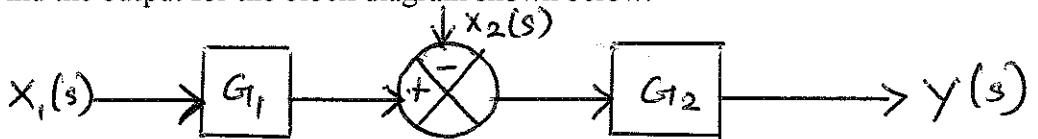
1. The super position principle is applicable to linear systems [1M]

2. The ratio of θ_1/θ_2 is equal to the ratio of $\frac{N_2}{N_1}$ (with respect to number of teeth) in gear train. [1M]

3. Mention the analogous quantities for the following for force – voltage analog? [2M]

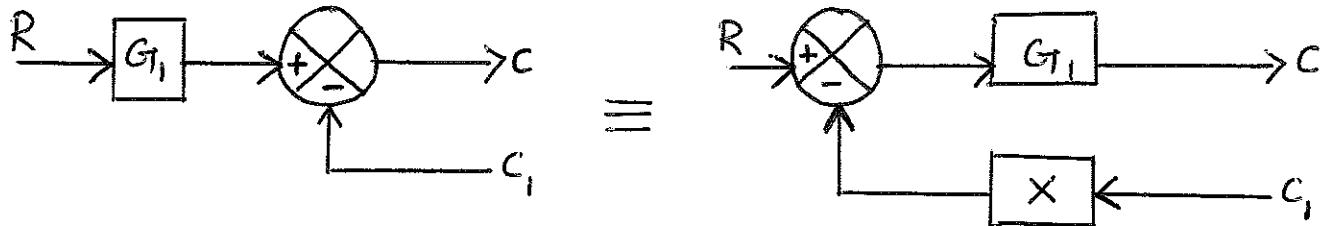
displacement - charge; velocity- velocity current

4. Find the output for the block diagram shown below. [2M]



$$Y(s) = \frac{X_1(s)G_{11} - X_2(s)}{G_{12}}$$

5. What is the value of 'X' for which the two blocks are equal? [3M]



$$X = \frac{1}{G_{11}} \quad [\text{PTO}]$$

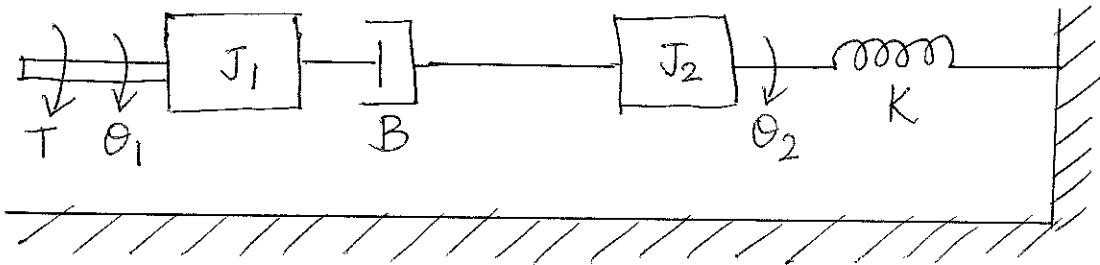
6. The error detector in a basic control loop compares command input signal with the signal obtained through feedback elements. [2M]

7. For the transient response analysis of Single-Input-Single-Output linear time-invariant systems, Transfer function representation is useful while a Multiple-Input-Multiple-Output system can be conveniently represented using the vector-matrix notation. [1M]

8. Write the differential equations governing the mechanical system shown below. [4M]

Ans: $\tau = J_1 \frac{d^2\theta_1}{dt^2} + B \frac{d\theta_1}{dt} (\theta_1 - \theta_2)$

$\theta = J_2 \frac{d^2\theta_2}{dt^2} + K\theta_2 + B \frac{d\theta_2}{dt} (\theta_2 - \theta_1)$



SET B