CBCS SCHEME

USN | | | | | | | | | | |

18EE61

Sixth Semester B.E. Degree Examination, July/August 2022
Control Systems

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Write the comparison between open loop and closed loop control system with example. **(06 Marks)**

b. For the mechanical system shown in Fig. Q1 (b). Draw the electrical equivalent network based on torque-voltage analogy.

Fig. Q1 (b) **(08 Marks)**

c. For the electrical network shown in Fig. Q1 (c), obtain the transfer function $\frac{V_0(s)}{V_i(s)}$.

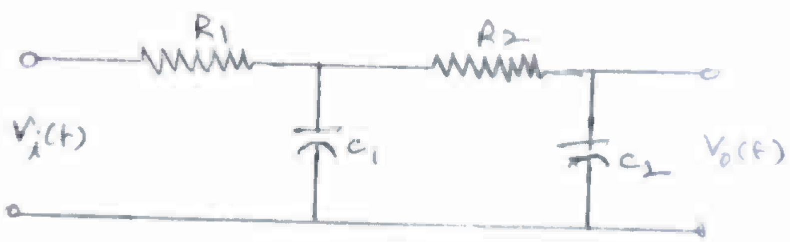


Fig. Q1 (c) **(06 Marks)**

OR

2 a. Define Transfer function. Also derive the transfer function relating displacement and excitation voltage drop for the armature controlled D.C.motor. **(06 Marks)**

b. Obtain the mathematical model for the mechanical system shown in Fig. Q2 (b). Draw the electrical equivalent based on F-I analogy.

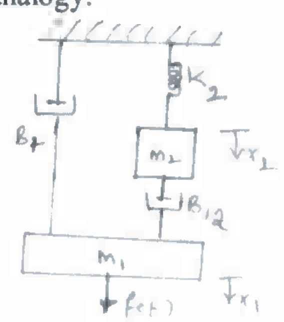


Fig. Q2 (b) **(08 Marks)**

c. Write the torque equation of the gear train shown in Fig. Q2 (c).

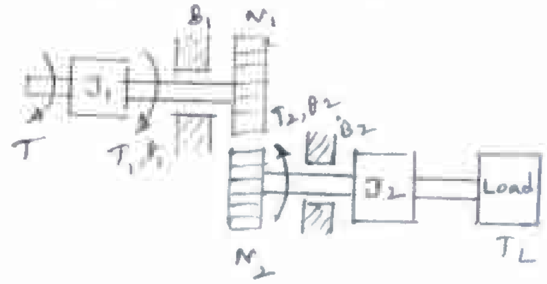


Fig. Q2 (c) **(06 Marks)**

Module-2

3 a. Using block diagram, reduction technique obtain transfer function $\frac{C(s)}{R(s)}$, whose block diagram shown in Fig. Q3 (a).

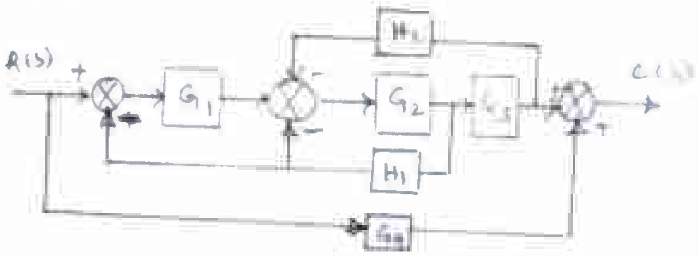
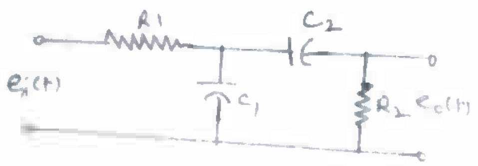


Fig. Q3 (a) **(10 Marks)**

b. Draw a block diagram for the electric circuit shown in Fig. Q3 (b) and hence evaluates Transfer function, $\frac{E_o(s)}{E_i(s)}$ using block diagram reduction techniques.



$R_1 = 100\ K\Omega$
$R_2 = 1\ M\Omega$
$C_1 = 10\ \mu F$
$C_2 = 1\ \mu F$

Fig. Q3 (b)

(10 Marks)

OR

4 a. Using Mason's gain formula determine the Transfer function of the given signal flow graph shown in Fig. Q4 (a).

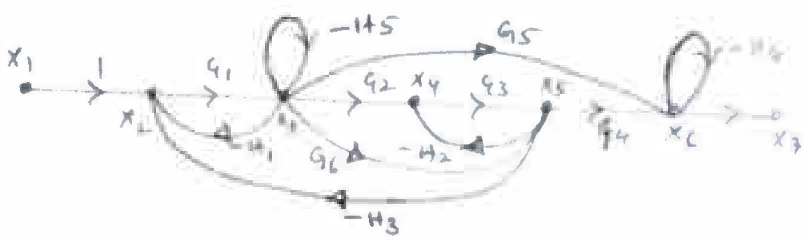


Fig. Q4 (a) **(10 Marks)**

b. A system is described by the following set of linear equation. Draw the signal flow graph and obtain the Transfer function $\frac{X_5}{X_1}$.

$$X_2 = a_{12}X_1 + a_{22}X_2 + a_{32}X_3$$
$$X_3 = a_{23}X_2 + a_{43}X_4$$
$$X_4 = a_{24}X_2 + a_{34}X_3 + a_{44}X_4$$
$$X_5 = a_{25}X_2 + a_{45}X_4$$

(10 Marks)

Module-3

5 a. Define time domain specifications of the second order system with diagram. **(05 Marks)**

b. A unity feedback system is characterized by an open loop Transfer Function $G(s) = \frac{K}{s(s+10)}$. Determine the gain 'K', so that system will have a damping ratio of 0.5. For the value of K determine the settling time, peak, overshoot, time to peak overshoot for a unit step input. **(07 Marks)**

c. Open loop Transfer Function of a unity feedback system is given by $G(s) = \frac{K}{s(1+TS)}$, where K and T are positive constants. By what factor should the amplifier gain 'K' be reduced so that peak overshoot of a unit step response of the system is reduced from 75% to 25%. **(08 Marks)**

OR

6 a. A certain feedback control system is described by the following Transfer Function.
$G(s) = \frac{K}{s^2(s+20)(s+30)}$, $H(s) = 1$. Determine order of system, Type number, Steady state error co-efficients and also determine the value of K to limit the steady state. Error 8 unit due to input $r(t) = 1 + 10t + 30t^2$. **(05 Marks)**

b. For the characteristic equation given below. Determine the number of roots of the characteristics equation in the RHS of S-plane
$s^6 + 3s^5 + 5s^4 + 9s^3 + 8s^2 + 6s + 4 = 0$ **(07 Marks)**

c. A unity feedback control system is characterized by the open loop transfer function, $G(s) = \frac{K(s+13)}{s(s+3)(s+7)}$. Using R.H. criteria (i) Calculate the range of K for the system to be stable (ii) Determine the value of K which will cause sustained frequency of oscillations in the closed loop system. What are the corresponding oscillation frequencies? **(08 Marks)**

Module-4

7 a. Draw the complete root locus plot for the system $G(s)H(s) = \frac{K}{s(s+2)(s+4)}$. Find the range of K, so that damping ratio of the closed loop system is 0.5. **(10 Marks)**

b. Draw the complete root locus for the system with $G(s)H(s) = \frac{K}{s(s+6)(s^2+4s+13)}$. Comment on stability. **(10 Marks)**

OR

8 a. The open loop transfer function of an unity feedback is $G(s) = \frac{K}{s(s+a)}$. (i) Find the value of 'K' and 'a'. So that resonant peak = 1.04 and resonant frequency = 11.5 rad/sec (ii) for the value of 'K' and 'a' found in part (i). Calculate the settling time and Bandwidth of the system. **(06 Marks)**

b. Draw the Bode plot for the system having,
$G(s) = \frac{10}{s(1+0.1s)(1+0.5s)}$, $H(s) = 1$
Determine the (i) Gain cross over frequency (ii) Phase crossover frequency (iii) Gain margin (iv) Phase margin. **(08 Marks)**

c. Find the open loop transfer function of a system whose approximate plot is as shown in Fig. Q8 (c).

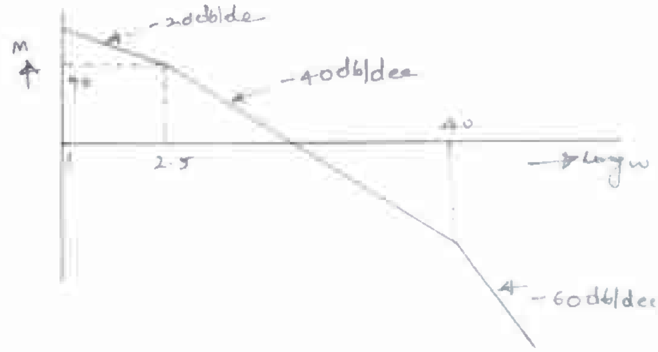


Fig. Q8 (c) **(06 Marks)**

Module-5

9 a. The open loop transfer function of a control system is $G(s)H(s) = \frac{1}{s(s+2)(s+10)}$. Sketch the Nyquist plot and calculate the value of K. **(10 Marks)**

b. What is controller? Explain the effect of P, I, PI and PID controller of a second order system. **(10 Marks)**

OR

10 a. Explain the step by step procedure of Lag compensating network. **(10 Marks)**

b. Design a Lead Compensator for a unity feedback system with an open loop transfer function $G(s) = \frac{K}{s(s+1)}$ for the specification of velocity error constant $K_V = 12\,sec^{-1}$ and phase margin as 40°. **(10 Marks)**

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Scheme & Solutions

Signature of Scrutinizer

Subject Title : CONTROL SYSTEM Subject Code : 18EE61

Question Number	Solution	Marks Allocated

Module-1

1(a)

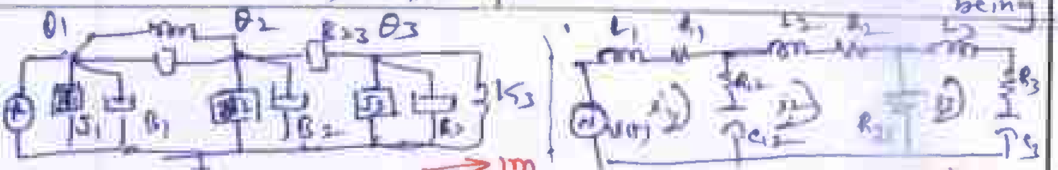
OLCS:
(i) output Independ of control action
(ii) more stable
(iii) feedback absent
(iv) Simple in construction
(v) operated in time basis
(vi) Field control, Traffic signal

CLCS:
(i) output some what depends on control action
(ii) less stable
(iii) feedback present
(iv) complicated in construction
(v) operated in accuracy basis
(vi) Armature control, Human being

$1 \times 6 = 6$

06

(b)



$\rightarrow$ 1m $\rightarrow$ 1m

$$T(t) = J_1 \frac{d^2\theta_1}{dt^2} + B_1\frac{d\theta_1}{dt} + B_{12}\frac{d(\theta_1-\theta_2)}{dt} + K_{12}(\theta_1-\theta_2)$$

$$J_2 \frac{d^2\theta_2}{dt^2} + B_2\frac{d\theta_2}{dt} + B_{23}\frac{d}{dt}(\theta_2-\theta_3) + B_{12}\frac{d}{dt}(\theta_2-\theta_1) + K_{12}(\theta_2-\theta_1) = 0$$

$$J_3 \frac{d^2\theta_3}{dt^2} + B_3\frac{d\theta_3}{dt} + K_3\theta_3 + B_{23}\frac{d}{dt}(\theta_3-\theta_2)$$

3m

T–V

$$v(t) = L_1\frac{di_1}{dt} + R_1 i_1 + R_{12}(i_1-i_2) + \frac{1}{C_{12}}\int(i_1-i_2)\,dt$$

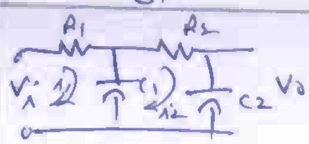
$$L_2\frac{di_2}{dt} + R_2 i_2 + R_{23}(i_2-i_3) + R_{12}(i_2-i_1) + \frac{1}{C_{12}}\int(i_2-i_1)\,dt = 0$$

$$L_3\frac{di_3}{dt} + R_3 i_3 + \frac{1}{C_3}\int i_3\,dt + R_{23}(i_3-i_2) = 0$$

3m

08

(c)



$$\left.\begin{aligned} R_1 i_1 + \frac{1}{C_1}\int(i_1-i_2)\,dt &= v_i \\ R_2 i_2 + \frac{1}{C_2}\int i_2\,dt + \frac{1}{C_1}\int(i_2-i_1) &= 0 \end{aligned}\right\} \text{2 m}$$

$$\begin{bmatrix} \left(R_1+\frac{1}{C_1 s}\right) & -\frac{1}{C_1 s} \\ -\frac{1}{C_1 s} & \left(R_2+\frac{1}{C_1 s}+\frac{1}{C_2 s}\right) \end{bmatrix}\begin{bmatrix} I_1(s) \\ I_2(s) \end{bmatrix} = \begin{bmatrix} V_i(s) \\ 0 \end{bmatrix} \quad V_0(s) = \frac{1}{C_2 s} I_2(s)$$

$\rightarrow$ 1m

$$I_2(s) = \frac{\Delta I(s)}{\Delta} = \qquad \Delta = \frac{R_1R_2C_1C_2s^2 + (R_1C_1+R_2C_2+R_1C_2)s+1}{C_1C_2s^2}$$

$$\Delta I(s) = \frac{V_i(s)}{C_1 s} \rightarrow \text{1m}$$

$$\frac{V_0(s)}{V_i(s)} = \frac{1}{s^2 R_1R_2C_1C_2 + [R_1C_1 + R_2C_2 + R_1C_2]s + 1} \rightarrow \text{2m}$$

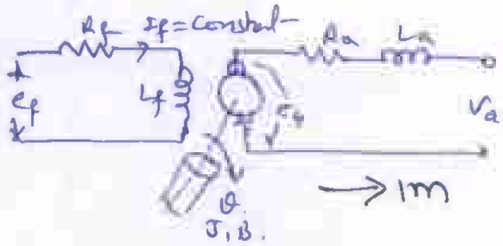
06

Subject Title: CONTROL SYSTEMS **Subject Code:** 18EE61

Question Number	Solution	Marks Allocated

2(a)

Definition — 1m.



$\longrightarrow$ 1m

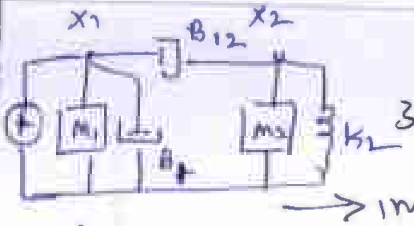
$T_m \propto I_a$
$T_m = K_T I_a$
$e_b = K \frac{d\theta}{dt}$
$L_a \frac{di_a}{dt} + R_a I_a + e_b = V_a$ } 02 m

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

$$\frac{\theta(s)}{V_a(s)} = \frac{K_T}{s[(R_a+sL_a)(Js+B)+K_T K_b]} \longrightarrow 2m$$

Marks: 06

(b)



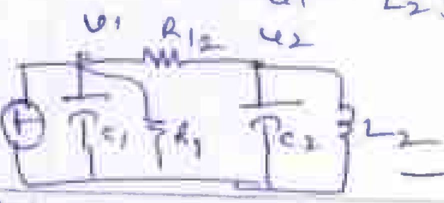
$\longrightarrow$ 1m

3m $\begin{cases} f(t) = M_1 \frac{d^2x_1}{dt^2} + B_1 \frac{dx_1}{dt} + B_{12} \frac{d(x_1-x_2)}{dt} \\ M_2 \frac{d^2x_2}{dt^2} + K_2 x_2 + B_{12} \frac{d}{dt}(x_2-x_1) = 0 \end{cases}$

f - I

$i(t) = C_1 \frac{dv_1}{dt} + \frac{v_1}{R_1} + \frac{v_1 - v_2}{R_{12}}$

$C_2 \frac{dv_2}{dt} + \frac{1}{L_2}\int v_2\, dt + \frac{v_2 - v_1}{R_{12}} = 0$ } 3 m



$\longrightarrow$ 1m

Marks: 08

(c)

Side-1

$T = J_1 \frac{d^2\theta_1}{dt^2} + B_1 \frac{d\theta_1}{dt} + T_1(t) \longrightarrow 1m$

Side 2

$T_2 = J_2 \frac{d^2\theta_2}{dt^2} + B_2 \frac{d\theta_2}{dt} + T_L$, $\frac{T_1}{T_2} = \frac{\theta_2}{\theta_1} = \frac{N_1}{N_2}$ $\longrightarrow$ 1m

$\frac{\theta_2}{\theta_1} = \frac{r_1}{r_2} = \frac{N_1}{N_2}$, $\frac{N_2}{N_1} T_1 = J_2 \frac{d^2\theta_2}{dt^2} + B_2 \frac{d\theta_2}{dt} + T_L$ $\longrightarrow$ 1m

$\therefore T_1 = \frac{N_1}{N_2} J_2 \frac{d^2\theta_2}{dt^2} + \frac{N_1}{N_2} B_2 \frac{d\theta_2}{dt} + \frac{N_1}{N_2} T_L$ $\longrightarrow$ 1m

$\therefore T = J_1 \frac{d^2\theta_1}{dt^2} + B_1 \frac{d\theta_1}{dt} + \frac{N_1}{N_2} J_2 \frac{d\theta_2}{dt} + \frac{N_1}{N_2} B_2 \frac{d\theta_2}{dt} + \frac{N_1}{N_2} T_L$

$\theta_2 = \frac{N_1}{N_2} \theta_1$ $\longrightarrow$ 1m

$\therefore T = \left[J_1 + \left(\frac{N_1}{N_2}\right)^2 J_2\right] \frac{d^2\theta_1}{dt^2} + \left[B_1 + \left(\frac{N_1}{N_2}\right)^2 B_2\right] \frac{d\theta_1}{dt} + \frac{N_1}{N_2} T_L$ $\longrightarrow$ 1m

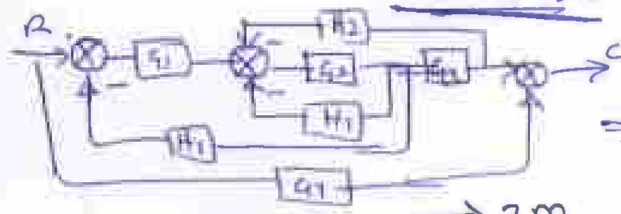
Marks: 06

Subject Title : CONTROL SYSTEM Subject Code : 18EE61

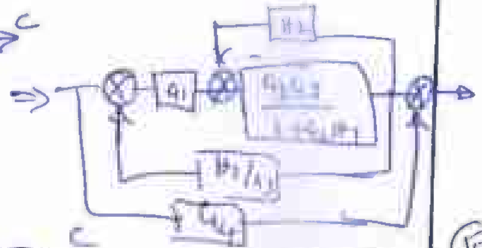
Question Number	Solution	Marks Allocated

module-2

3 (a)



$\longrightarrow$ 2m



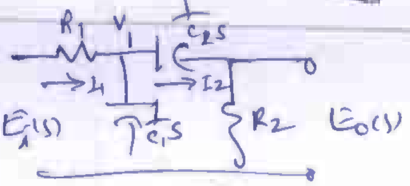
$\longrightarrow$ 2m

$\longrightarrow$ 2m

$$\frac{C(s)}{R(s)} = \frac{G_1G_2G_3+G_4}{1+G_2H_1+G_2G_3H_1+G_1G_2H_1}$$ $\longrightarrow$ 4

(10)

(b)



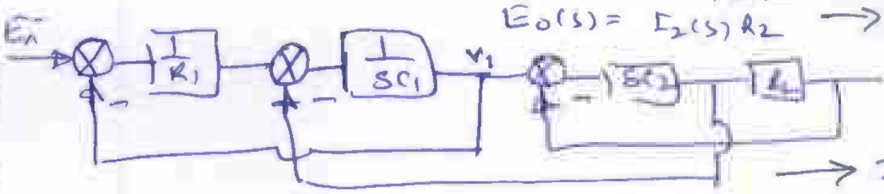
$\longrightarrow$ 2m

$I_1(s) = \frac{E_i(s) - V_1(s)}{R_1}$ $\longrightarrow$ 1m

$V_1(s) = [I_1(s) - I_2(s)] \times \frac{1}{C_1 s}$ $\longrightarrow$ 1m

$I_2(s) = \frac{V_1(s) - E_0(s)}{1/sC_2} = (V_1 - E_0)C_2 s$ $\longrightarrow$ 1m

$E_0(s) = I_2(s) R_2$ $\longrightarrow$ 1m



$\longrightarrow$ 2m

(10)

$$\frac{E_0(s)}{E_i(s)} = \frac{sC_2R_2}{s^2R_1R_2C_1C_2 + s[R_1C_1+R_2C_2+R_1C_2]+1}$$ $\longrightarrow$ 2m

$$\frac{E_0(s)}{E_i(s)} = \frac{s}{s^2+2.1s+1}$$ $\longrightarrow$ 1m

4 (a)

$P_1 = G_1G_2G_3G_4$
$P_2 = G_1G_5$
$P_3 = G_1G_4G_6$
$\longrightarrow$ 1m

$L_1 = -G_1H_1$
$L_2 = -H_5$
$L_3 = -G_3H_2$
$L_4 = -H_4$
$L_5 = -G_1G_2G_3H_3$
$L_6 = -G_1G_4H_3$
2m

$L_{n1} = L_1L_3 = G_1G_3H_1H_2$
$L_{n2} = L_1L_5 = G_1H_1H_4$
$L_{n3} = L_2L_5 = G_3H_2H_5$
$L_{n4} = L_5L_6$
$L_{n5} = L_3L_5$
$L_{n6} =$
2m

$\Delta = 1 - [L_1+L_2+L_3+L_4+L_5+L_6] + [L_{n1}+L_{n2}+L_{n3}+L_{n4}+L_{n5}+L_{n6}]$ $\longrightarrow$ 2m

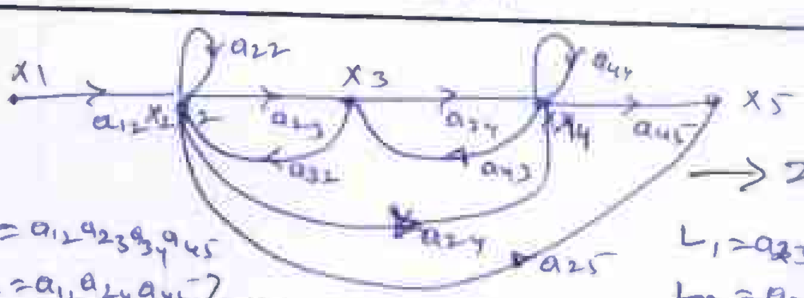
$T = \frac{\sum P_k \Delta_k}{\Delta} = \frac{P_1\Delta_1 + P_2\Delta_2 + P_3\Delta_3 + P_4\Delta_4}{\Delta}$

(10)

$\Delta_1 = 1$
$\Delta_2 = 1 + G_2H_2$
$\Delta_3 = 1$
1m

$$T = \frac{G_1G_2G_3G_4 + G_1G_5(1+G_2H_2) + G_1G_4G_6}{\Delta}$$ $\longrightarrow$ 2m

Subject Title : CONTROL SYSTEM Subject Code : 18EE61

Question Number	Solution	Marks Allocated
4(b)	 $\rightarrow 2m$	
	$P_1 = a_{12}a_{23}a_{34}a_{45}$ $P_2 = a_{12}a_{24}a_{45}$ $P_3 = a_{12}a_{25}$ } 1m $L_1 = a_{23}a_{32}$ $L_2 = a_{34}a_{43}$ $L_3 = a_{22}$ $L_4 = a_{44}$ } 2m $L_5 = a_{24}a_{43}a_{32}$ $L_{n1} = L_1L_4$ $L_{n2} = L_3L_4$ $L_{n3} = L_2L_3$ } 2m $\Delta_1 = 1$ $\Delta_2 = 1$ } 1m. $\Delta_3 = 1-[L_2+L_4)$ $\Delta = 1-[L_1+L_2+L_3+L_4+L_5]+[L_{n1}+L_{n2}+L_{n3}]$ $\frac{X_5}{X_1} = \frac{\sum P_k\Delta_k}{\Delta} = \frac{P_1\Delta_1+P_2\Delta_2+P_3\Delta_3}{\Delta}$ 2m { $= \frac{a_{12}a_{23}a_{34}a_{45}+a_{12}a_{24}a_{45}+a_{12}a_{25}[1-a_{34}a_{43}+a_{44}]}{1-a_{23}a_{32}-a_{34}a_{43}-a_{22}-a_{44}-a_{24}a_{43}a_{32}+a_{23}a_{32}a_{44}+a_{22}a_{44}+a_{34}a_{43}a_{22}}$	10
	MODULE-3	
5(a)	Definition:- Delay time, Rise time, peak time, peak overshoot, settling time $1\times5 = 5m$	
(b)	$\frac{C(s)}{R(s)} = \frac{K}{s^2+10s+K} = \frac{\omega_n^2}{s^2+2\xi\omega_ns+\omega_n^2}$ $\omega_n = \sqrt{K}$, $2\xi\omega_n = 10$ $\omega_n = 10$ $K = \omega_n^2 = 100$ $t_s = \frac{4}{\xi\omega_n} = 0.8sec$ $\%M_p = e^{\frac{-\xi\omega_n}{\sqrt{1-\xi^2}}}\times100 = 0.163\%$ $t_p = \frac{\pi}{\omega_n\sqrt{1-\xi^2}} = 0.363 sec$	05
(c)	$\frac{C(s)}{R(s)} = \frac{K}{s^2+\frac{1}{T}s+\frac{K}{T}} = \frac{\omega_n^2}{s^2+2\xi\omega_ns+\omega_n^2} \rightarrow 2m$ $\omega_n = \sqrt{\frac{K}{T}}$, $\xi = \frac{1}{2\sqrt{KT}} \rightarrow 1m$ $M_p = 0.75$ $\xi = \xi_1$ $K = K_1$ $M_p = 0.25$ $\xi = \xi_2$ $K = K_2$ $0.75 = e^{-\xi_1\pi/\sqrt{1-\xi_1^2}}$, $0.25 = e^{-\xi_2\pi/\sqrt{1-\xi_2^2}}$ $\xi_1 = 0.09116 \rightarrow 1m$ $\xi_2 = 0.40371 \rightarrow 1m$ $\frac{\xi_1}{\xi_2} = \sqrt{\frac{K_2}{K_1}}$ $\therefore \frac{K_2}{K_1} = 0.05098$ $K_2 = 0.05098K_1$ } 02m	07

Subject Title : CONTROL SYSTEM   Subject Code : 18EE61

Question Number	Solution	Marks Allocated
6 (a)	see below	05
(b)	see below	07
(c)	see below	08

6 (a)

$$G(s) = \frac{K}{s^2(s+20)(s+30)}$$

order of system = 4 → 1m

Type No: 2 → 1m

$r(t) = 1 + 10t + 60\frac{t^2}{2}$

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

$K_v = \lim_{s\to 0} sG(s)H(s) = \infty$

$K_a = \lim_{s\to 0} s^2 G(s)H(s) = \frac{K}{600}$

} 02m

$e_{ss} = \frac{A}{1+K_p} + \frac{B}{K_v} + \frac{C}{K_a}$

$8 = \frac{1}{1+\infty} + \frac{10}{\infty} + \frac{60}{K/600}$

} 01m

$K = 450$

(b)

s^6	1	5	8	4
s^5	3	9	6	
s^4	2	6	4	
s^3	0	0		
s^2				
s^1				
s^0				

→ 2m

Difficulty No: 2

$A(s) = 2s^4 + 6s^2 + 4$

$\frac{dA(s)}{ds} = 8s^3 + 12s$ } 1m

s^6	1	5	8	4
s^5	3	9	6	
s^4	2	6	4	
s^3	8	12		
s^2	3	4		
s^1	1.3			
s^0	4			

} 2m

$A(s) = s^4 + 3s^2 + 2 = s^4 + 2s^2 + s^2 + 2$

(s^2+2)

$= s^2(s^2+2) + 1(s^2+2)$

$= (s^2+2)(s^2+1)$

$s = \pm j\sqrt{2}, \quad s = \pm j1$

} 2m

LHS = 2

RHS = 0

Img = 4

(c)

$1 + G(s)H(s) = 0$

$1 + \frac{K(s+13)}{s(s+3)(s+7)} = 0$

$s^3 + 10s^2 + (21+K)s + 13K = 0$ → 2m

s^3	1	21+K
s^2	10	13
s^1	$\frac{210-3K}{10}$	–
s^0	13K	

} 3m

$13K > 0$

$\boxed{K > 0}$

$\frac{210-3K}{10} > 0$

$\boxed{K < 70}$

range of K

$\boxed{0 < K < 70}$

→ 1m

$10s^2 + 13K = 0$

$s = \pm j9.53$

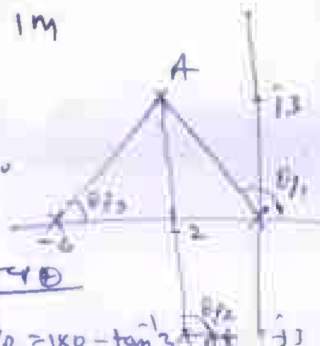
sustained frequency of oscillation

$\omega = 9.53$ rad/sec

} 02m

→ 2m

Subject Title : CONTROL SYSTEM **Subject Code :** 18EE61

Question Number	Solution	Marks Allocated
7(a)	**Module-4** $G(s)H(s) = \dfrac{K}{s(s+2)(s+4)}$ Step①:- There are 3 poles $s=0,-2,-4$, $n=3$ There is no zero $m=0$. → 1m No of root loci $= n-m = 3$ Step② No of Asymptotes $= n-m = 3$ $\theta_q = \dfrac{(2q+1)180}{n-m} = 60^\circ, 180^\circ, 300$ } 2m $\sigma_A = \dfrac{\Sigma P - \Sigma Z}{n-m} = \dfrac{-2-4}{3} = -2$ Step③ Break away point- $\dfrac{dK}{ds} = 0$ $1+G(s)H(s)=0$ $1 + \dfrac{K}{s(s+2)(s+4)}$ $K = -[s^3+6s^2+8s]$ } 2m $\dfrac{dK}{ds} = -[3s^2+12s+8] = 0$ $s = -3.15, -0.85$ Break away point $= s = -0.85$ Step④;- no need angle of departure & arrival. Step⑤ crossing point on imaginary axis s^3 | 1 8 s^2 | 6 K s^1 | $\frac{48-K}{6}$ 0 s^0 | K $K>0$ $\frac{48-K}{6} > 0$ $K < 48$ $6s^2+K=0$ $s^2=-8$ $s=\pm j2.8$ } 2m plot – 2m $\xi = 0.5$ ∴ value of $K = \dfrac{L_{p_1}L_{p_2}L_{p_3}}{\text{length of zer}}$ $= \dfrac{1.3 \times 1.8 \times 3.5}{1}$ $= 8.19$ → 1m	10
7(b)	Step① There are 4 poles $s=0$, $s=-6$ $s=-2\pm j3$ $n=4$ There is no zero $m=0$ } 1m No of root loci $= n-m = 4$ Step② No of Asymptotes $= n-m = 4$ $q = 0,1,2,3$ $\theta_q = \dfrac{(2q+1)}{n-m} \times 180 = 45^\circ, 135, 225, 315^\circ$ } 2m $\sigma_A = \dfrac{\Sigma P - \Sigma Z}{n-m} = -2.5$ Step③ $\dfrac{dK}{ds} = 0$ $1+G(s)H(s)=0$ $K = [s^4+10s^3+37s^2+78s]$ $\dfrac{dK}{ds} = 0$ $s^3+7.5s^2+18.5s+19.5=0$ } 2M $s = -4.201$ -1.64 ± 1.386 Break away point $= -4.201$ Step⑤  Step④ $\theta p_1 = 180 - \tan^{-1}\frac{3}{2} = 122$ $\theta p_2 = 90$ $\theta p_3 = \tan^{-1}\frac{3}{4} = 38^\circ$ } 02 $\phi_d = 180 - (122+90+38)$ $= -70^\circ$ ϕ_d at A^* $\phi_d = 70^\circ$	10

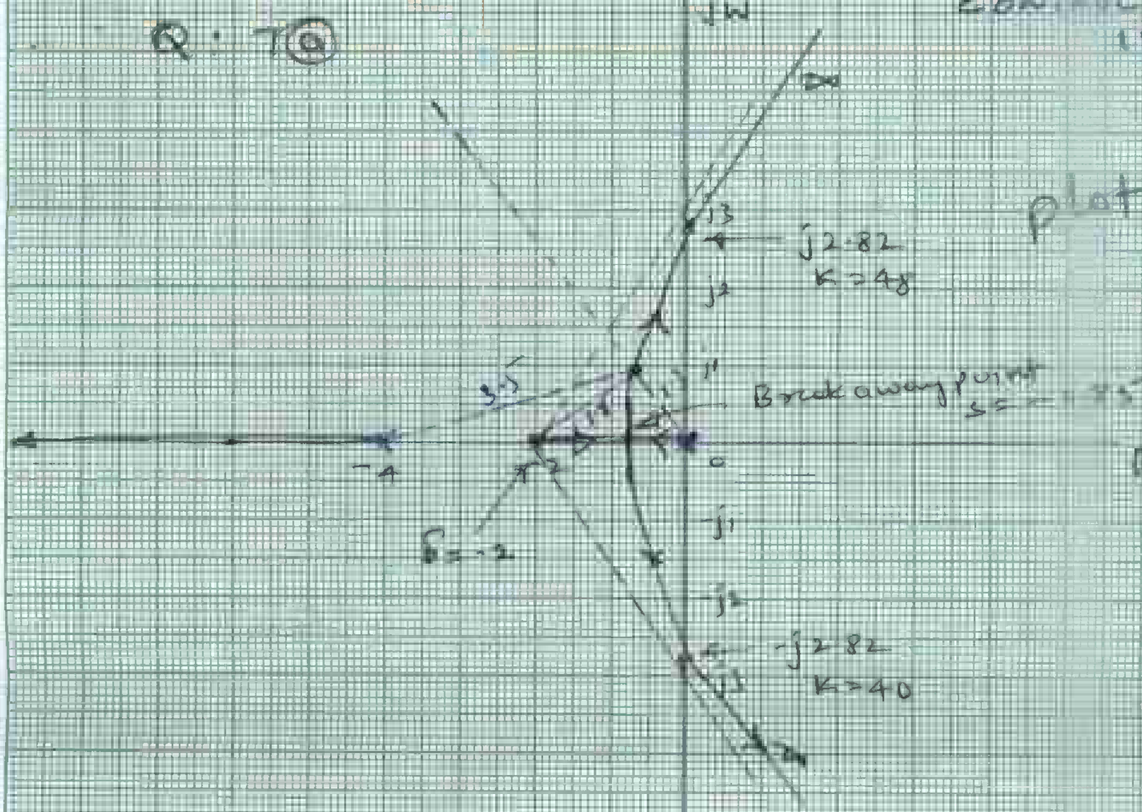
crossing point on Img axis

s^4 \| 1 37 K
s^3 \| 10 78
s^2 \| 29.2 K
s^1 \| $\frac{2277.6-K}{29.2}$
s^0 \| K

$K>0$
$\frac{2277.6-K}{29.2} > 0$
$K < 2277.6$

$29.2s^2+K=0$
$s = \pm j2.8$
$\omega = 2.8$ rad/sec

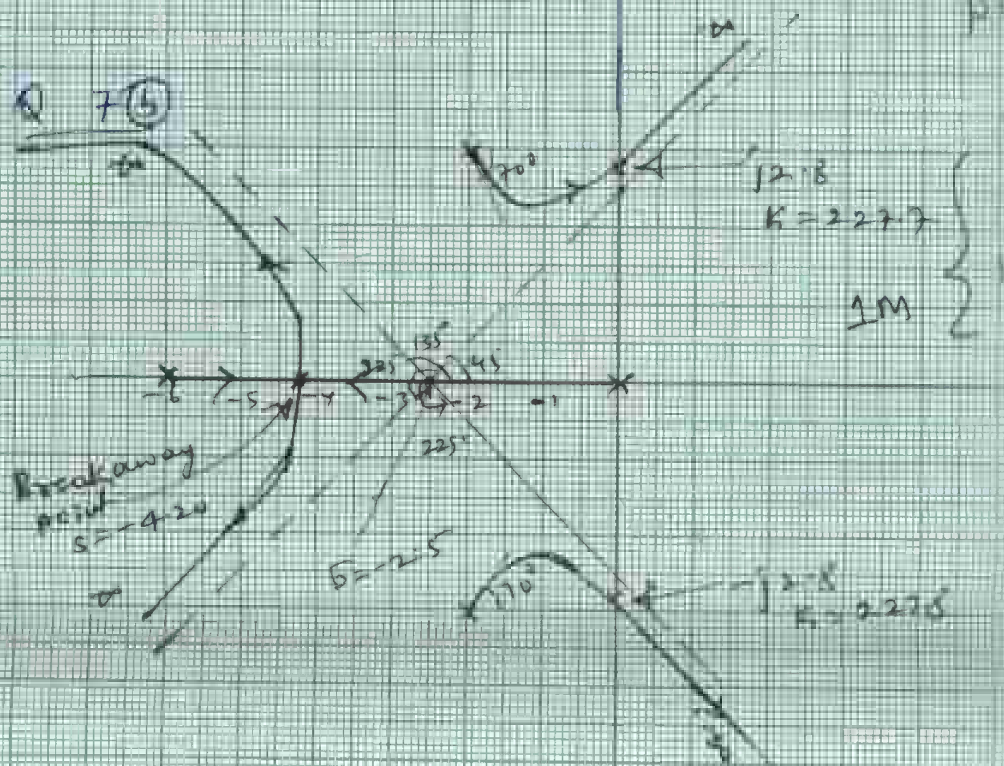
Q. 7(a)



plot — 2M

plot — 2M

Q 7(b)



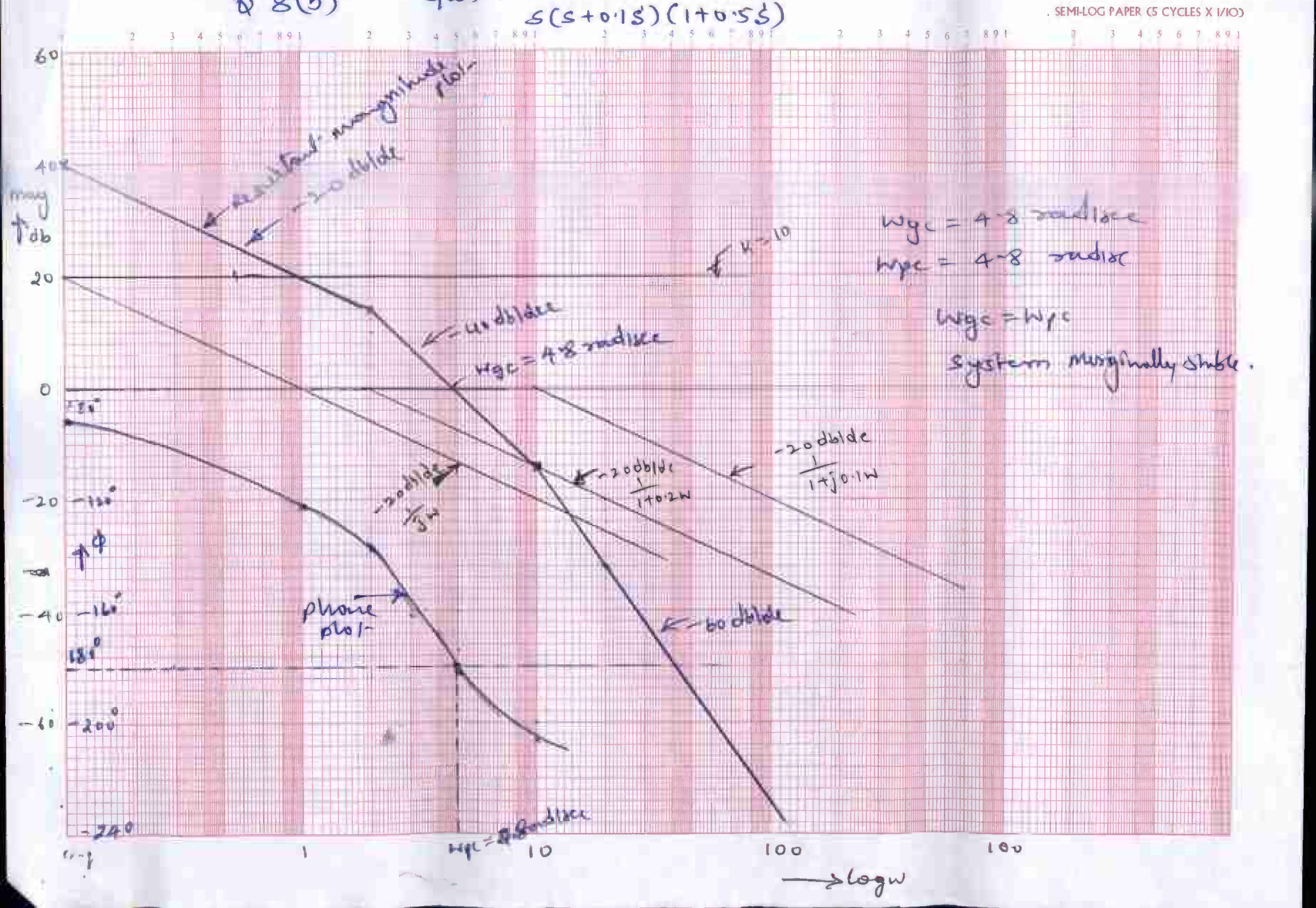
1M

K < 227.76 stable

K > 227.76 unstable

K = 227.76 marginally stable

Q 8(b) $G(s) = \dfrac{10}{s(s+0.1s)(1+0.5s)}$



Subject Title : CONTROL SYSTEM Subject Code : 18EE61

Question Number	Solution	Marks Allocated

8 (a)

$$\frac{C(s)}{R(s)} = \frac{K}{s^2+as+K} = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} \rightarrow 1M$$

$\left.\begin{array}{l}\omega_n = \sqrt{K} \\ \xi = \frac{a}{2\sqrt{K}}\end{array}\right\} 1M$ $\quad M_r = \frac{1}{2\xi\sqrt{1-\xi^2}} = 1.04$ $\quad \omega_r = \omega_n\sqrt{1-2\xi^2} = 11.5$

$\xi = 0.6021$ $\quad \omega_n = 22.027$ $\rightarrow 1m$

$\therefore K = \omega_n^2 = 485.1 \rightarrow 1m$

$a = \xi 2\sqrt{K} = 26.52$

$BW = \omega_n\sqrt{1-2\xi^2+\sqrt{2-4\xi^2+4\xi^4}} = 25.23$ rad/s $\rightarrow 1m$

$T_s = \frac{4}{\xi\omega_n} = 0.3016$ sec — 1m

06

(b)

$$G(j\omega) = \frac{10\angle 0}{\omega\angle 90 \times \sqrt{1^2+(0.1\omega)^2}\angle \tan^{-1}0.1\omega \times \sqrt{1^2+(0.5\omega)^2}\angle \tan^{-1}0.5\omega}$$

$\phi = -90 - \tan^{-1}0.1\omega - \tan^{-1}0.5\omega \rightarrow$ 01 ~~2~~ m

corner frequency $\omega_{c_1} = \frac{1}{0.5} = 2$ rad $\quad \omega_{c_2} = \frac{1}{0.1} = 10$ rad/sec

term	C.F	slope	change in slope
K=10	—		
$\frac{1}{j\omega}$	—	−20db/dc	−20db/dc
$\frac{1}{1+j0.5\omega}$	2	−20	−40
$\frac{1}{1+j0.1\omega}$	10	−2	−60

01 $\rightarrow$ ~~2~~m

ω	φ
0	−90
0.1	−93.43
1	
2	−122.3
5	−146.31
10	−184.76
~~15~~	−217
15	−228

01 $\rightarrow$ ~~2~~M

08

02 $\left\{\begin{array}{l}\omega_{gc} = 4.8 \text{ rad/sec} \\ \omega_{pc} = \cancel{4}\,8 \text{ rad/sec} \\ G_m = 0 \text{ db} \\ P_m = 180+\phi_{gc} = 180-180 = 0°\end{array}\right.$

plot — 03 m

$\omega_{gc} = \omega_{pc}$ $\therefore$ System marginally stable

(c)

$\omega = 2.5$ rad/sec

mag at ω_{c_2} = A at ω_{c_1} + change in slope from ω_{c_1} to ω_{c_2} $\times \log\frac{\omega_{c_2}}{\omega_{c_1}}$

$40 = A$ at $\omega_{c_1} + (-20\times\log\frac{2.5}{1})$

$A = 47.95$ db

$20\log K = 47.95$

$K = 10^{47.95/20}$

$\boxed{K = 250} \rightarrow 2m$

06

first line have slope −20db/dec due to $= \frac{1}{s} \rightarrow 1M$

$\omega = 2.5$ rad/sec slope change from −20 to −40 db due 1st order factor in denominator $= \frac{1}{1+s/2.5} \rightarrow 1M$

$\omega = 40$ slope changes from −40 to −60 due to $\frac{1}{1+s/40} \rightarrow 1m$

$$G(s) = \frac{250}{s(1+\frac{s}{2.5})(1+s/40)} = \frac{250}{s(1+0.4s)(1+0.025s)}$$

$\rightarrow$ 2m

Sub: CONTROL SYSTEM   Code: 18EC61

Solution

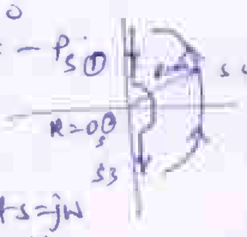
Q NO | Module-5 | Marks

9(a) $G(s) = \dfrac{K}{s(s+2)(s+10)}$

Step 1: $P = 0$

Step 2: $N = -P$

Step 3:



$\longrightarrow$ 2 M

Step 4: put $s = j\omega$

$G(j\omega) = \dfrac{K}{j\omega(j\omega+2)(j\omega+10)}$ $\longrightarrow$

$M = \dfrac{K}{\omega\sqrt{4+\omega^2}\sqrt{100+\omega^2}}$, $\phi = -90 - \tan^{-1}\frac{\omega}{2} - \tan^{-1}\frac{\omega}{10}$ $\longrightarrow$

$\longrightarrow$ 2 M

$S = j\infty$ to $S = +j0$

$\omega \to \infty$ to $\omega \to 0$

Section-I

$\omega \to \infty$	$0\angle -270°$	$-90-(-270°)$ $= 180°$
$\omega = 0$	$\infty\angle -90$	

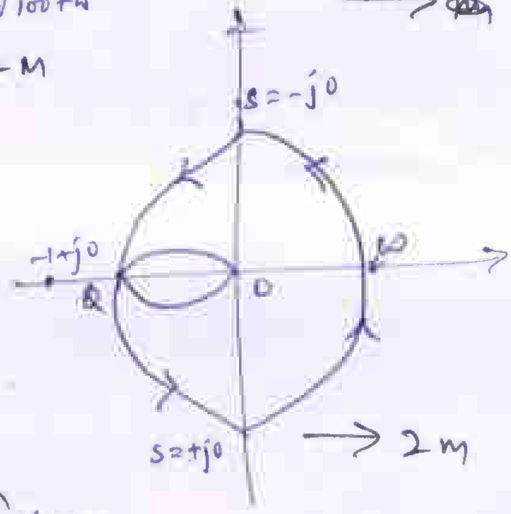
$\longrightarrow$ 1 M

Section-II

$\omega = +0$	$\infty\angle -90$	$90-(-90)$
$\omega = -0$	$\infty\angle 90$	$= 180°$

$\longrightarrow$ 1 M

Section-III mirror image of section about real axis



$\longrightarrow$ 2 M

(10)

Step 5:- $G(j\omega) = \dfrac{K(-j\omega)(10-j\omega)(2-j\omega)}{(j\omega)(-j\omega)(10+j\omega)(10-j\omega)(2+j\omega)(2-j\omega)}$

$$\left.\begin{aligned} &= \frac{-12K\omega^2}{D} - \frac{Kj\omega(20-\omega^2)}{D} \\ &D = \omega^2(4+\omega^2)(100+\omega^2) \\ &\text{Equating imag: } \omega(20-\omega^2) = 0 \end{aligned}\right\} \text{02 M}$$

$\omega_{pc} = \sqrt{20}$

Sub real part $Q = \dfrac{-12 \times K \times 20}{20 \times (20+4)(100+20)} = -\dfrac{K}{240}$

$0Q < 1$ $\boxed{K < 240}$ $0 < K < 240$

(b) Controller — 2 M

P - controller — 2

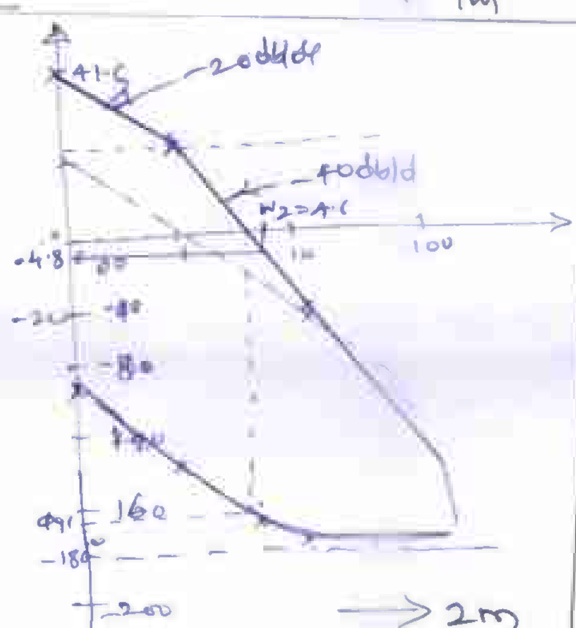
I - Controller — 2

PI — Controller — 2

PID — controller 2

(10)

Subject Title :- CONTROL SYSTEMS. Subject code: 18EE61

Q.No	Solution	Marks
1 (a)	Procedure for lag compensator Step ① Determine the value of K to satisfy the specified error ② For this value of K Draw Bode plot. Find PM ③ If ϕ_s = specified PM ϵ = margin safety 5 to 15° $\phi_2 = \phi_s + \epsilon$ ④ Find frequency ω_{c2} ⑤ measure gain of uncompensated system at ω_{c2} $\omega_{c2} = 20 \log \beta$ ⑥ choose upper corner frequency $\omega_2 = 1/\tau$. $\omega_2 = \frac{1}{\tau} = \frac{\omega_{c2}}{2}$ to $\frac{\omega_{c2}}{10}$ ⑦ Thus β & τ are determined $G_c(s) = \frac{1}{\beta}\left[\frac{s+\frac{1}{\tau}}{s+1/\beta\tau}\right]$ ⑧ Draw the Bode plot of the compensated system. $G_c(s) = \frac{(s+z_c)}{s+p_c} = \frac{s+1/\tau}{s+1/\beta\tau}$, $\frac{E_0}{E_i} = \frac{R_2 + 1/Cs}{R_1+R_2+\frac{1}{Cs}}$	each step 1 × 8 = 08 R1, R2, C, e_i, e_o → 1M → 1M 10
(b)	$G(s) = \frac{K}{s(s+1)}$ $K = 12$ $G(s) = \frac{12}{s(s+1)} =$ $G(j\omega) = \frac{12}{j\omega(j\omega+1)} = \frac{12\angle 0}{\omega\angle 90 \sqrt{1^2+\omega^2} \angle \tan^{-1}\frac{\omega}{1}}$ $\phi = -90 - \tan^{-1}\omega \longrightarrow$ 1M magnitude $\omega = 0.1$ $A = 20\log\frac{12}{0.1} = 41.5$ $\omega = 1$ $A = 20 \log 12 = 21.5$ $\omega = \omega_H = 10$ $A = A$ at ω_{c1} + slope from ω_{c1} to ω_H $\log\frac{\omega_H}{\omega_{c1}}$ $= 21.5 + (-20)\log\frac{10}{1}$ $= 1.5 \longrightarrow$ 2M  → 2m ω : φ — 0.1 : −95; 1 : −135; 2 : −153.4; 5 : −168.6; 10 : −174; 500 : 179.80 } 1M $PM = 180 + \phi_{gc}$ $= 180 - 165$ $= 15°$ PM specified = 40° phase lead = 40 − 15 + 5 = 30° $\alpha = \frac{1-\sin\phi_m}{1+\sin\phi_m} = 0.33$ } 02 m Gain = $-10 \log \frac{1}{}$	

From plot 4.6 rad.

$W_{c_2} = W_m = 4.6$

Corner freq. $= \frac{1}{T} = W_M \sqrt{\alpha}$

$= 4.6\sqrt{0.33}$

$= 2.64$

$W_2 = \frac{1}{\alpha T} = \frac{W_M}{\sqrt{\alpha}} = \frac{4.6}{0.33} = 8$ rad/sec (10)

$$\left.G_c = \frac{s + \frac{1}{T}}{s + 1/\alpha T} = \frac{s + 2.64}{s + 8}\right\} 02$$

$$G_c(s) = \frac{0.33(1 + 0.378s)}{1 + 0.125s}$$