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CONTROL SYSTEMS

EC | EE

Date of Test : 22/07/2026

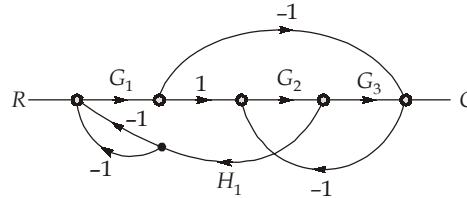
ANSWER KEY ➤

1. (b)	7. (b)	13. (d)	19. (b)	25. (c)
2. (c)	8. (b)	14. (b)	20. (b)	26. (d)
3. (b)	9. (b)	15. (a)	21. (c)	27. (c)
4. (a)	10. (a)	16. (c)	22. (b)	28. (d)
5. (d)	11. (d)	17. (c)	23. (c)	29. (a)
6. (c)	12. (d)	18. (d)	24. (c)	30. (d)

DETAILED EXPLANATIONS

1. (b)

The signal flow graph for the given block diagram can be drawn as



As per signal flow graph, the loops are

$$L_1 = G_2 G_3 (-1) = -G_2 G_3$$

$$L_2 = G_1 G_2 H_1 (-1) = -G_1 G_2 H_1$$

$$L_3 = G_1 G_2 H_1 (-1) = -G_1 G_2 H_1$$

$$L_4 = G_1 (-1) (-1) G_2 H_1 (-1) = -G_1 G_2 H_1$$

$$L_5 = G_1 (-1) (-1) G_2 H_1 (-1) = -G_1 G_2 H_1$$

∴

$$\begin{aligned} \Delta &= 1 - (L_1 + L_2 + L_3 + L_4 + L_5) \\ &= 1 - (-G_2 G_3 - G_1 G_2 H_1 - G_1 G_2 H_1 - G_1 G_2 H_1 - G_1 G_2 H_1) \\ &= 1 + G_2 G_3 + 2G_1 G_2 H_1 + 2G_1 G_2 H_1 \\ &= 1 + G_2 G_3 + 4G_1 G_2 H_1 \end{aligned}$$

and

$$P_1 = G_1 G_2 G_3$$

$$\Delta_1 = 1$$

$$P_2 = G_1 (-1) = -G_1$$

$$\Delta_2 = 1$$

∴

$$\frac{C}{R} = \frac{P_1 \Delta_1 + P_2 \Delta_2}{\Delta} = \frac{G_1 (G_2 G_3 - 1)}{1 + G_2 G_3 + 4G_1 G_2 H_1}$$

2. (c)

Given,

$$y(t) = 2te^{-5t}$$

$$x(t) = u(t)$$

Taking Laplace transform, we get,

$$Y(s) = \frac{2}{(s+5)^2} \quad \text{and} \quad X(s) = \frac{1}{s}$$

∴ Overall transfer function,

$$\frac{Y(s)}{X(s)} = \frac{2s}{(s+5)^2}$$

3. (b)

The characteristic equation of the given system is,

$$1 + G(s)H(s) = 1 + \frac{K}{4s^3 + 2s^2 + 3s} = 0$$

or $4s^3 + 2s^2 + 3s + K = 0$

Using Routh's tabular form,

s^3	4	3
s^2	2	K
s^1	$\frac{6-4K}{2}$	
s^0	K	

For stability,

$$K > 0$$

and $\frac{6-4K}{2} > 0$

or $4K < 6$

$$K < \frac{3}{2}$$

So, the required condition is $0 < K < \frac{3}{2}$.

4. (a)

The closed loop transfer function,

$$\frac{C(s)}{R(s)} = \frac{12}{s(s+5)+12} = \frac{12}{s^2+5s+12}$$

Here, on comparing with standard second order transfer function, we get,

$$\omega_n = \sqrt{12}$$

and $\xi\omega_n = \frac{5}{2}$

For 2% tolerance,

$$\tau_s = \frac{4}{\xi\omega_n} = \frac{4}{5/2} = \frac{8}{5} = 1.6 \text{ sec}$$

5. (d)

$$G(s)H(s) = \frac{K(s^2 + 2s + 10)}{(s^2 + 6s + 10)}$$

For, $s^2 + 6s + 10 = 0$

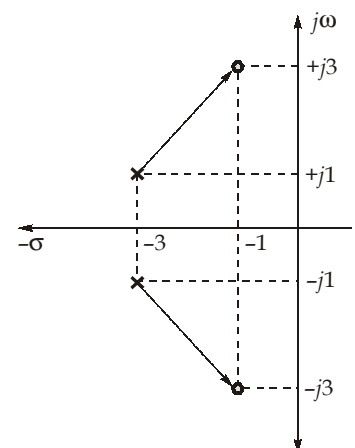
$$s = \frac{-6 \pm \sqrt{36-40}}{2} = -3 \pm j$$

For, $s^2 + 2s + 10 = 0$

$$s = \frac{-2 \pm \sqrt{4-40}}{2} = -1 \pm j3$$

$$\therefore G(s)H(s) = \frac{K(s+1+j3)(s+1-j3)}{(s+3+j)(s+3-j)}$$

$\therefore$ There will be no break points.



6. (c)

The characteristic equation is,

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

$$s(s+3)(s+4) + 5(s+2) = 0$$

$$s^3 + 7s^2 + 12s + 5s + 10 = 0$$

$$s^3 + 7s^2 + 17s + 10 = 0$$

s^3	1	17
s^2	7	10
s^1	$\frac{17 \times 7 - 10}{7}$	
s^0	10	

$\therefore$ The total number of sign change in the first column of Routh array is zero.

$\therefore$ Number of poles on LHS = 3.

7. (b)

The standard form of transfer function of the compensator is

$$G_c(s) = \alpha \frac{1+sT}{1+\alpha sT}$$

$\therefore$ In time constant form,

$$G_c(s) = \frac{1(1+100s)}{10(1+10s)}$$

Here, $T = 100$ and $\alpha T = 10$

or $\alpha = \frac{10}{100} = 0.1$

$\therefore \alpha < 1 \therefore$ Lead compensator.

8. (b)

The characteristic equation is given by

$$|sI - A| = 0$$

$$\begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} = \begin{bmatrix} s & -1 \\ 1 & s \end{bmatrix}$$

$$\therefore |sI - A| = \begin{bmatrix} s & -1 \\ 1 & s \end{bmatrix} = s^2 + 1$$

$$s = \pm j$$

As the roots are purely imaginary, thus the system has undamped response.

9. (b)

For $\omega = 0$, the plot starts at 0° , that means there will be no pole at origin, hence the type of the system is 0.

For $\omega = \infty$, the plot terminates at 270° i.e., the order of the system should be 3.

10. (a)

As the initial slope is 0 dB/dec.

$$20 \log K = -20$$

$$\log K = -1$$

or $K = 0.1$

at $\omega = 1$ rad/sec, the slope changes to 20 dB/dec, thereby adds a zero at $\omega = 1$ rad/sec

at $\omega = 10$ rad/sec, the slope changes to 0 dB/dec thereby adds a pole at $\omega = 10$ rad/sec.

at $\omega = 100$ rad/sec, the slope changes to -40 dB/dec thereby adds two poles at $\omega = 100$ rad/sec

∴ Resultant transfer function is,

$$T(s) = \frac{0.1 \left(\frac{s}{1} + 1 \right)}{\left(\frac{s}{10} + 1 \right) \left(\frac{s}{100} + 1 \right)^2} = \frac{10^4 (s+1)}{(s+10)(s+100)^2}$$

11. (d)

The location of the poles are given by, $-\xi\omega_n \pm j\omega_d$... (i)

where, ξ = damping ratio

ω_n = natural frequency of oscillation

ω_d = damped frequency of oscillation

Using maximum peak overshoot, the value of ξ can be obtained as

$$e^{-\pi\xi/\sqrt{1-\xi^2}} = 0.15$$

$$\frac{\xi}{\sqrt{1-\xi^2}} = 0.604$$

Squaring both the sides,

$$\xi^2 = 0.364(1 - \xi^2)$$

$$\text{or } \xi^2 = \frac{0.364}{1.364} = 0.267$$

$$\text{or } \xi = 0.517 \quad \dots (ii)$$

$$\text{now, peak time, } \tau_p = \frac{\pi}{\omega_d} = 3$$

$$\text{or } \omega_d = \frac{\pi}{3} = 1.047 \text{ rad/sec}$$

$$\therefore \omega_d = \omega_n \sqrt{1-\xi^2} \quad \dots (iii)$$

∴ From equation (ii) and (iii), we have

$$\omega_n = \frac{\omega_d}{\sqrt{1-\xi^2}} = \frac{1.047}{\sqrt{1-0.517^2}}$$

$$\omega_n = 1.223 \text{ rad/sec} \quad \dots (iv)$$

∴ Location of poles are,

$$\begin{aligned} P &= -\xi\omega_n \pm j\omega_d \\ &= -(0.517 \times 1.223) \pm j1.047 \\ &= -0.632 \pm j1.047 \end{aligned}$$

12. (d)

Steady state error,

$$\begin{aligned}
 e_{ss} &= \lim_{s \rightarrow 0} sE(s) \\
 &= \lim_{s \rightarrow 0} s \times \frac{R(s)}{1 + G(s)H(s)} \\
 &= \lim_{s \rightarrow 0} \frac{s \times \left(2 + \frac{5}{s}\right) \times \frac{1}{s}}{1 + \frac{K}{s(s+3)}} \\
 &= \lim_{s \rightarrow 0} \frac{s(2s+5)}{s[s(s+3) + K]} \\
 &= \lim_{s \rightarrow 0} \frac{(2s+5) \times s(s+3)}{(s^2 + 3s + K)} \\
 &= \lim_{s \rightarrow 0} \frac{(2s+5)(s+3)}{s^2 + 3s + K} \\
 2.75 &= \frac{15}{K} \\
 \text{or} \quad K &= \frac{15}{2.75} = 5.45
 \end{aligned}$$

13. (d)

For any point to lie on the root locus the angle condition must be satisfied.

$$\angle G(s)H(s) \big|_{s=(-1+j2)} = \pm 180^\circ$$

$$\therefore G(s)H(s) \big|_{s=(-1+j2)} = \frac{K(-1+j2+1)}{(-1+j2+9)(-1+j2+3)} = \frac{K(j2)}{(8+j2)(2+j2)}$$

$$\begin{aligned}
 \therefore \angle G(s)H(s) \big|_{s=-1+j2} &= 90^\circ - \tan^{-1}\left(\frac{2}{8}\right) - \tan^{-1}(1) \\
 &= 90^\circ - 14.036^\circ - 45^\circ \\
 &= 30.96^\circ
 \end{aligned}$$

$$\therefore \angle G(s)H(s) \big|_{s=s_0} \neq \pm 180^\circ$$

Angle condition does not satisfy.

14. (b)

The steady state error is defined by

$$\begin{aligned}
 e_{ss} &= \lim_{s \rightarrow 0} \frac{s \times \frac{1}{s^2}}{1 + \frac{(s+\alpha)}{s} \times \frac{(s+2)}{s^2-1}} \\
 &= \lim_{s \rightarrow 0} \frac{(s^2-1)}{s(s^2-1) + (s+\alpha)(s+2)}
 \end{aligned}$$

$$e_{ss} = -\frac{1}{2\alpha}$$

$$\therefore S_{\alpha}^{e_{ss}} = \frac{\frac{\partial e_{ss}}{\partial \alpha}}{\alpha} = \frac{\frac{\partial e_{ss}}{\partial \alpha}}{\alpha} \times \frac{\alpha}{e_{ss}} = \frac{\partial}{\partial \alpha} \left(\frac{-1}{2\alpha} \right) \times \frac{\alpha}{-\frac{1}{2\alpha}}$$

$$= -\frac{\alpha^2}{\alpha^2} = -1$$

15. (a)

The characteristic equation is,

$$K(s-2) + (s+1)(s+2) = 0$$

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

$$\text{or } s^2 + (3+K)s + (2-2K) = 0$$

...(i)

It is required that one pole should lie at origin. Let other pole lie at $-x$.

$\therefore$ Required characteristic equation becomes

$$(s+0)(s+x) = 0$$

$$\text{or } s^2 + xs = 0$$

...(ii)

On comparing (i) and (ii), we have

$$2 - 2K = 0$$

$$2K = 2$$

$$\text{or } K = 1$$

16. (c)

The characteristic equation is,

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

$$s^2(s+a) + K\left(s + \frac{4}{3}\right) = 0$$

For $K = 6$

$$s^3 + as^2 + 6s + 8 = 0$$

Using Routh's method for 3rd order system for stability,

$$6a \geq 8$$

$$a \geq \frac{8}{6}$$

$$a \geq \frac{4}{3}$$

$\therefore$ For system to be unstable $a < \frac{4}{3} = 1.33$

17. (c)

The characteristic equation is,

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

$$s(s+1)(s+2)(s+4) + K = 0$$

$$s^4 + 7s^3 + 14s^2 + 8s + K = 0$$

Using Routh's tabular form, we have

s^4	1	14	K
s^3	7	8	
s^2	12.86	K	
s^1	$\frac{102.88 - 7K}{12.86}$		
s^0	K		

For system to be oscillatory

$$\frac{102.8 - 7K}{12.86} = 0 \Rightarrow K \approx 14.697$$

$\therefore$ Auxiliary equation,

$$12.86s^2 + K = 0$$

$$s^2 = \frac{-K}{12.86} = -\frac{14.697}{12.86} = -1.142$$

or

$$s = \pm j1.07$$

$\therefore$

$$\omega = 1.07 \text{ rad/sec}$$

18. (d)

$$\frac{V_0(s)}{V_s(s)} = \frac{R_2}{\frac{R_1}{R_1Cs + 1} + R_2} = \frac{R_2(R_1Cs + 1)}{R_1 + R_2 + R_1R_2Cs}$$

By rearranging, we get,

$$\frac{V_0(s)}{V_s(s)} = \frac{R_2}{R_1 + R_2} \times \left(\frac{1 + R_1Cs}{1 + \frac{R_2}{R_1 + R_2} \cdot R_1Cs} \right)$$

$$\therefore \alpha = \frac{R_2}{R_1 + R_2}$$

19. (b)

The phase margin is given by,

$$\text{PM} = 180^\circ + \phi$$

$$60^\circ = 180^\circ + \left[-90^\circ - \tan^{-1} \omega - \tan^{-1} \frac{\omega}{3} \right]$$

$$-30^\circ = -\tan^{-1} \left(\frac{\frac{\omega}{1} + \frac{\omega}{3}}{1 - \frac{\omega^2}{3}} \right)$$

$$\tan 30^\circ = \frac{\omega + \frac{\omega}{3}}{1 - \frac{\omega^2}{3}}$$

$$\frac{1}{\sqrt{3}} = \frac{\frac{4\omega}{3}}{1 - \frac{\omega^2}{3}}$$

or $1 - \frac{\omega^2}{3} = \frac{4\omega}{\sqrt{3}}$

$$\Rightarrow \omega^2 + 4\sqrt{3}\omega - 3 = 0$$

On solving the above equation, we get,

$$\omega = 0.408 \text{ rad/sec and } -7.33 \text{ rad/sec}$$

Considering positive value of frequency for $\omega = \omega_{gc}$, we have,

$$|G(j\omega)H(j\omega)|_{\omega = \omega_{gc}} = 1$$

$$\frac{K}{\omega\sqrt{\omega^2 + 1}\sqrt{\omega^2 + 9}} = 1$$

$$K = 0.408\sqrt{1.166} \times \sqrt{9.166}$$

$$K = 1.33$$

20. (b)

From the given state model, the transfer function can be calculated as

$$\begin{aligned} T(s) &= C(sI - A)^{-1} B \\ &= \begin{bmatrix} 1 \\ 2 \end{bmatrix}^T \begin{bmatrix} s & -1 \\ 2 & s+5 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 1 \end{bmatrix} \\ &= [1 \ 2] \times \frac{1}{s(s+5)+2} \begin{bmatrix} s+5 & 1 \\ -2 & s \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} \\ &= [1 \ 2] \times \frac{1}{s(s+5)+2} \begin{bmatrix} 1 \\ s \end{bmatrix} \end{aligned}$$

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

∴ Open loop transfer function for unity negative feedback system becomes

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

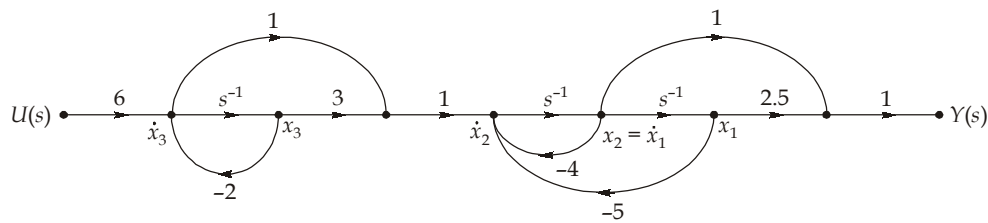
For unit step input,

$$K_p = \lim_{s \rightarrow 0} G(s)H(s) = \lim_{s \rightarrow 0} \frac{1+2s}{s^2+3s+1} = 1$$

$$\therefore e_{ss} = \frac{1}{1+K_p} = \frac{1}{2} = 0.5$$

21. (c)

The state diagram of the system shown in below figure is the cascade of the state diagram of two sub-systems.



From this state diagram, the input output equations can be written as

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = -5x_1 - 4x_2 + 3x_3 + 6u$$

$$\dot{x}_3 = -2x_3 + 6u$$

$$y = 2.5x_1 + x_2$$

$$\therefore \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ -5 & -4 & 3 \\ 0 & 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 6 \\ 6 \end{bmatrix} u$$

$$y = [2.5 \quad 1 \quad 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

22. (b)

The closed loop transfer function has the characteristic equation,

$$(s+1)(s+10) + 10K = 0$$

$$s^2 + 11s + 10 + 10K = 0$$

On comparing with standard second order system, we have,

$$2\xi\omega_n = 11$$

$$\text{or } \xi\omega_n = \frac{11}{2}$$

$$\therefore M_r = 1.58$$

$$\therefore M_r = \frac{1}{2\xi\sqrt{1-\xi^2}} = 1.58$$

$$\frac{1}{1.58} = 2\xi\sqrt{1-\xi^2}$$

$$0.100 = \xi^2(1-\xi^2)$$

$$\text{or } \xi^4 - \xi^2 + 0.100 = 0$$

$$\text{or } \xi^2 = 0.8872 \text{ and } 0.112$$

$$\Rightarrow \xi = 0.9419 \text{ and } 0.334$$

$$\therefore \xi < 0.707$$

$$\therefore \xi = 0.334 \text{ has to be considered}$$

$$\text{and hence, } \omega_n = \frac{11}{2 \times 0.334} = 16.434$$

$$\therefore 10 + 10K = \omega_n^2 = 270.089$$

$$10K = 260.089$$

$$\text{or } K = 26.008 \approx 26$$

23. (c)

The initial part of the resultant magnitude plot is a straight line with a slope of -20 dB/decade. It corresponds to a pole at the origin.

Corner frequencies = 2.5 rad/sec, 40 rad/sec

Each corner frequency contributes a slope of -20 dB/dec, so both corner frequencies represent the poles of system,

$$\text{T.F.} = \frac{K}{s \left(\frac{s}{\omega_{c1}} + 1 \right) \left(\frac{s}{\omega_{c2}} + 1 \right)}$$

Here, $\omega_{c1} = 2.5$
and $\omega_{c2} = 40$

$$\text{T.F.} = \frac{K}{s \left(\frac{s}{2.5} + 1 \right) \left(\frac{s}{40} + 1 \right)}$$

In low frequency region $\omega < \omega_{c1}$

approximate, $\text{T.F.} = \frac{K}{s}$

$$T(j\omega)|_{\text{dB}} = 20 \log K - 20 \log \omega$$

at $\omega = \omega_{c1}$, $|T(j\omega)| = 40 \text{ dB}$

$$40 = 20 \log K - 20 \log 2.5$$

$$20 \log K = 47.96,$$

$$\log K = 2.399$$

$$K = 10^{2.4} = 251$$

So,
$$T(s) = \frac{251}{s(1 + 0.4s)(1 + 0.025s)}$$

24. (c)

For controllability, $|Q_c| = |B : AB| \neq 0$

Given,
$$A = \begin{bmatrix} 0 & 1 \\ -1 & -3 \end{bmatrix}, \quad B = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$$

$$AB = \begin{bmatrix} 0 & 1 \\ -1 & -3 \end{bmatrix} \begin{bmatrix} 1 \\ 2 \end{bmatrix} = \begin{bmatrix} 2 \\ -7 \end{bmatrix}$$

$$|Q_c| = \begin{bmatrix} 1 & 2 \\ 2 & -7 \end{bmatrix}$$

$$Q_c = -7 - 4 = -11 \neq 0$$

The system is controllable,

For observability, $|Q_o| = |C^T : A^T C^T| \neq 0$

$$A^T C^T = \begin{bmatrix} 0 & -1 \\ 1 & -3 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} -1 \\ -2 \end{bmatrix}$$

$$|Q_o| = \begin{vmatrix} 1 & -1 \\ 1 & -2 \end{vmatrix} = -2 + 1 = -1 \neq 0$$

The system is observable.

25. (c)

$$G(s) = \frac{1 + 0.5s}{1 + 1.25s}$$

By comparing standard equation,

$$\frac{E_o(s)}{E_i(s)} = \frac{1 + sT}{1 + s\beta T}$$

Where, $\beta = \frac{R_1 + R_2}{R_2}$

and $T = R_2 C$
 $T = 0.5$

$$R_2 = \frac{0.5}{10 \times 10^{-6}} = 0.5 \times 10^5 = 50 \text{ k}\Omega$$

$$\beta T = 1.25$$

$$\beta = 2.5 = 1 + \frac{R_1}{R_2}$$

$$R_1 = 1.5 R_2 = 75 \text{ k}\Omega$$

26. (d)

The characteristic equation is

$$s^2 + 1.6s + 16 = 0$$

comparing with the second order characteristic equation i.e.

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

$$2\xi\omega_n = 1.6$$

and $\omega_n = \sqrt{16} = 4 \text{ rad/sec}$

then damping ratio for the system without derivative feedback control is

$$\xi = \frac{1.6}{2\omega_n} = \frac{1.6}{2 \times 4} = 0.2$$

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

$$\xi' = \frac{2\xi\omega_n + \omega_n^2 T_d}{2\omega_n} = \xi + \frac{\omega_n T_d}{2}$$

$$0.8 = 0.2 + \frac{4T_d}{2}$$

$$T_d = 0.3$$

27. (c)

Forward paths:

$$\begin{aligned} F_1 &= G_1 G_2 G_3 G_4 & ; & \Delta_1 = 1 \\ F_2 &= G_1 G_6 G_4 & ; & \Delta_2 = 1 \\ F_3 &= G_1 G_7 & ; & \Delta_3 = 1 - G_5 \end{aligned}$$

Individual loops:

$$L_1 = G_2 H_1 \quad ; \quad L_2 = G_5$$

Two non-touching loops,

$$\begin{aligned} L_{12} &= G_2 H_1 (G_5) \\ \Delta &= 1 - G_2 H_1 - G_5 + G_2 H_1 G_5 \end{aligned}$$

$$\therefore \frac{X_5}{X_1} = \frac{G_1 G_2 G_3 G_4 + G_1 G_4 G_6 + G_1 G_7 (1 - G_5)}{1 - G_2 H_1 + G_2 G_5 H_1 - G_5}$$

28. (d)

Characteristics equation is

$$s^5 - 2s^4 - 2s^3 + 4s^2 + s - 2 = 0$$

$$\begin{array}{l|rrr} s^5 & 1 & -2 & 1 \\ s^4 & -2 & 4 & -2 \\ s^3 & 0(-1) & 0(1) & 0 \\ s^2 & 2 & -2 & 0 \\ s^1 & 0(4) & 0 & 0 \\ s^0 & -2 & & \end{array}$$

Auxiliary equation-1 is,

$$-2s^4 + 4s^2 - 2 = 0$$

$$\frac{d}{ds}(-2s^4 + 4s^2 - 2) = 0$$

$$-8s^3 + 8s = 0$$

$$-s^3 + s = 0$$

Auxiliary equation-2 is,

$$2s^2 - 2 = 0$$

$$\frac{d}{ds}(2s^2 - 2) = 0$$

$$4s = 0$$

3 sign changes in the first column.

Therefore 3 poles are in RHP out of which 2 are symmetric.

29. (a)

$$1 + KG = 0$$

$$s^3 + 6s^2 + 12s + Ks + 8 - 4K = 0$$

$$(s^3 + 6s^2 + 12s + 8) + K(s - 4) = 0$$

$$1 + \frac{K(s-4)}{s^3 + 6s^2 + 12s + 8} = 0$$

∴ Open loop transfer function,

$$G(s) = \frac{(s-4)}{s^3 + 6s^2 + 12s + 8}$$

s^3	1	12
s^2	6	8
s^1	$\frac{72-8}{6} = 10.66$	
s^0	8	

There is no sign change in first column of RH table.

∴ Open loop system is stable.

30. (d)

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

$$K_v = \lim_{s \rightarrow 0} s \cdot \frac{K(s+10)(s+15)}{s(s+3)(s+7)(s+20)}$$

$$K_v = \frac{K(10)(15)}{(3)(7)(20)} = \frac{K(5)}{14}$$

$$e_{ss} = \frac{25}{K_v} = \frac{25}{K(5)} \times 14$$

$$0.1 = \frac{5 \times 14}{K}$$

$$K = \frac{5 \times 14}{0.1} = 700$$

