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CONTROL SYSTEM

EC-EE

Date of Test : 30/08/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. **(b)**

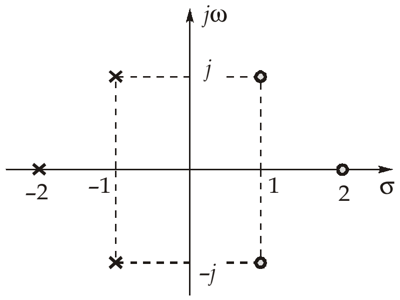
As the three blocks are connected in cascade the overall transfer function is given by the multiplication of individual blocks.

$$\therefore \quad x_1 \times x_2 \times x_3 = \frac{(s+1)}{s(s+2)(s+3)}$$

$$\frac{1}{s(s+2)} \times \frac{(s+2)}{(s+3)} \times x_3 = \frac{(s+1)}{s(s+2)(s+3)}$$

$$x_3 = \frac{(s+1)}{(s+2)}$$

2. **(d)**



3. **(b)**

Here, the encirclement to the critical point is 1 (in clock wise direction) and 2 (in counter clockwise direction).

$$\therefore \quad N = -1 + 2 = 1$$

4. **(d)**

$$T(s) = \frac{C(s)}{R(s)} = \frac{10(s+2)}{(s^2+4s+8)}$$

$\therefore$ The step response $C(s)$ is,

$$C(s) = \frac{10(s+2)}{(s^2+4s+8)} \times R(s) = \frac{10(s+2)}{s(s^2+4s+8)}$$

and the steady state response is,

$$\lim_{t\to\infty} c(t) = \lim_{s\to 0} sC(s) = \lim_{s\to 0} s\frac{10(s+2)}{s(s^2+4s+8)} = \frac{10}{4} = 2.5$$

5. **(b)**

The roots of the characteristic equation are given by,

$$s_{1,2} = -\xi\omega_n \pm \omega_n\sqrt{1-\xi^2}$$

Here, $\quad -\xi\omega_n = -3$

$$\Rightarrow \quad \omega_n = \frac{3}{\xi} \qquad \text{...(i)}$$

and $$\omega_n\sqrt{1-\xi^2} = 2 = \omega_d \quad \text{...(ii)}$$

By putting the value of ω_n in equation (ii), we get,

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

$$\frac{9}{\xi^2}\times(1-\xi^2) = 4$$

or $$9(1-\xi^2) = 4\xi^2$$

$$9 - 9\xi^2 - 4\xi^2 = 0$$

or $$13\xi^2 = 9$$

or $$\xi = \sqrt{\frac{9}{13}} = \frac{3}{\sqrt{13}}$$

6. **(d)**

The steady state offset is given by,

$$e_{\text{off}} = \lim_{s\to 0} sC(s)\Big|_{R(s)=0}$$

When $R(s) = 0$, $$C(s) = D(s) - C(s)\left[\frac{4K}{(2s+1)}\right]$$

$$C(s) = \frac{D(s)}{1+\frac{4K}{(2s+1)}}$$

$\therefore$ $$e_{\text{off}} = \lim_{s\to 0}\frac{s\cdot\frac{0.3}{s}(2s+1)}{(2s+1)+4K}$$

or $$e_{\text{off}} = \frac{0.3}{4K+1}$$

For $e_{\text{off}} = 0$, $$K = \infty$$

7. **(a)**

The characteristic equation is given by,

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

Here, $$G(s) = \frac{4}{s(s+0.2)} \text{ and } H(s) = (1+2s)$$

$\therefore$ $$1+\frac{4(1+2s)}{s(s+0.2)} = 0$$

$$s^2 + 0.2s + 8s + 4 = 0$$

$$s^2 + 8.2s + 4 = 0$$

8. **(b)**

From the above Bode plot,

For section de, slope is –20 dB/dec

$\therefore$ $$-20 = \frac{y-0}{\log 8 - \log 16}$$

$$y = 6.02 \text{ dB}$$

Now, for section bc, slope is –20 dB/dec

$$\therefore \qquad -20 = \frac{16 - 6.02}{\log\omega_1 - \log 4}$$

$$\omega_1 = 1.268 \text{ rad/sec}$$

To find value of gain K

$$y = mx + c$$

$$16 = -40 \log 1.268 + 20 \log K$$

$$K = 10.14$$

From all the result, transfer function is,

$$T(s) = \frac{10.14\left(\frac{s}{1.268}+1\right)\left(\frac{s}{4}+1\right)}{s^2\left(\frac{s}{8}+1\right)}$$

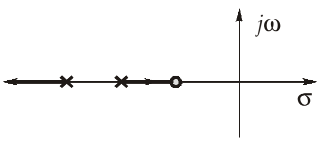
$$T(s) = \frac{16(s+1.268)(s+4)}{s^2(s+8)}$$

9. (b)

$$\text{Centroid} = \frac{\sum P - \sum Z}{P - Z} = \frac{-(2+3)+1}{1} = -4$$

$$\text{Angle of asymptotes} = \frac{(2q+1)180°}{P-Z} = 180°,\ 540° \text{ and } 900°$$

$\therefore$ Approximated plot is,



10. (b)

The Routh's table can be formed as

s^3	4	4
s^2	$3(s^2)$	$3(0)$
s^1	$(0)6$	(0)
s^0	$\frac{18-0}{6} = 3$	

as there is no sign change in the first column of Routh array thus, there will be no pole lie on the RHS of s-plane. Also the row of zero occurs that indicates the complex conjugate poles exists on $j\omega$ axis.

11. (c)

The closed loop transfer function of the system is

$$\frac{C(s)}{R(s)} = \frac{4s+1}{4s^2+4s+1} = \frac{1}{4} \times \frac{4s+1}{\left(s+\frac{1}{2}\right)^2}$$

For unit step input, $R(s) = \frac{1}{s}$

$$C(s) = \frac{1}{4} \times \frac{4s+1}{s\left(s+\frac{1}{2}\right)^2} \quad \text{. . . (i)}$$

12. **(d)**

Given, $$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)} = \frac{K+p}{s^2+qs+p}$$

For $H(s) = 1$, $$\frac{G(s)}{1+G(s)} = \frac{K+p}{s^2+qs+p}$$

or $$G(s)\,[s^2 + qs + p] = (K + p) + G(K + p)$$

or $$G(s) = \frac{K+p}{s^2+qs+p-K-p} = \frac{K+p}{s^2+qs-K}$$

This is a type-0 system.
For a type-0 system, for unit ramp input,

$$e_{ss} = \infty$$

13. **(b)**

Using the Routh's tabular form

s^6	1	8	20	16
s^5	2	12	16	0
s^4	$2(s^4)$	$12(s^2)$	$16(s^0)$	
s^3	8	24	0	
s^2	6	16	0	
s^1	$\frac{16}{6}$	0	0	
s^0	16			

Since there is no sign change in the first column of the Routh array, the system does not have any pole in the RHS of s-plane. However the row of zeros occur which gives the auxiliary equation

$$A(s) \Rightarrow 2s^4 + 12s^2 + 16 = 0$$
$$\Rightarrow s^4 + 6s^2 + 8 = 0$$

and the roots are given by,

$$s = \pm j\sqrt{2}, \pm j2$$

Hence the system is said to be marginally stable.

14. **(d)**

As per root locus transfer function

$$G(s)\,H(s) = \frac{k}{(s+4)(s^2+2s+2)}$$

CE: $$1 + G(s)\,H(s) = 0$$

$$s(s^2 + 2s + 2) + 4\,(s^2 + 2s + 2) + k = 0$$

$$s^3 + 6s^2 + 10s + (8 + k) = 0$$

s^3	1	10
s^2	6	$8 + k$
s^1	$-\dfrac{(8+k)-60}{6}$	0
s^0	$8 + k$	0

Row, $\quad s^1 = 0$

$\Rightarrow \quad 8 + k = 60$

$$k = 52$$

For calculation of intersection points,

$$6s^2 + (8 + k) = 0$$

$$6s^2 + (60) = 0$$

$$s^2 = -10$$

$$s = \pm j\sqrt{10}$$

Thus points of intersection are,

$$s = \pm j\omega = \pm j\sqrt{10}$$

15. (b)

The maximum phase lead is given by,

$$\phi_m = \sin^{-1}\left(\frac{1-\alpha}{1+\alpha}\right)$$

For high pass filter/lead compensator,

$$\tau = R_1C$$

and $\quad \alpha = \dfrac{R_2}{R_1 + R_2}\;;\; \alpha < 1$

By putting the value of α in the above relation, we get,

$$\phi_m = \sin^{-1}\left(\frac{1-\dfrac{R_2}{R_1+R_2}}{1+\dfrac{R_2}{R_1+R_2}}\right)$$

$$= \sin^{-1}\left(\frac{R_1+R_2-R_2}{R_1+R_2+R_2}\right) = \sin^{-1}\left(\frac{R_1}{R_1+2R_2}\right)$$

16. (a)

The SFG shown in figure has two forward paths and five loops. There are no pairs of two loops which are not touching each other, and all the loops are touching both the forward paths. The forward paths and the gains associated with them are as follows:

Forward path $x_1 - x_2 - x_3 - x_4 - x_5 - x_6$;

$$M_1 = (1)\,(G_1)\,(G_2)\,(G_3)\,(1)$$

$$= G_1\,G_2\,G_3;$$

$$\Delta_1 = 1$$

Forward path $x_1 - x_2 - x_5 - x_6$;

$$M_2 = (1)\,(G_4)\,(1) = G_4$$
$$\Delta_2 = 1$$

The loops and gains are as follows:

Loop $x_2 - x_3 - x_2$; $\quad L_1 = G_1(-H_1) = -G_1H_1$

Loop $x_2 - x_3 - x_4 - x_2$; $\quad L_2 = G_1G_2(-H_2) = -G_1G_2H_2$

Loop $x_3 - x_4 - x_5 - x_3$; $\quad L_3 = G_2G_2(-H_3) = -G_2G_3H_3$

Loop $x_2 - x_5 - x_3 - x_2$; $\quad L_4 = G_4(-H_3)(-H_1) = G_4H_3H_1$

Loop $x_2 - x_5 - x_3 - x_4 - x_2$; $\quad L_5 = G_4(-H_3)(G_2)(-H_2)$

$$= G_4G_2H_3H_2$$

Applying Mason's gain formula, the transfer function is

$$\frac{x_6}{x_1} = \frac{M_1\Delta_1 + M_2\Delta_2}{\Delta}$$

$$= \frac{G_1G_2G_3 + G_4}{1 + G_1H_1 + G_1G_2H_2 + G_2G_3H_3 - G_4H_3H_1 - G_4G_2H_3H_2}$$

17. (b)

Characteristics equation of this system is

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

$$1 + \frac{K(s^2+16)}{s(s+4)} = 0$$

Breakaway points can be calculated as

$$K = \frac{-s(s+4)}{s^2+16}$$

Differentiating above equation with respect to 's'

$$\frac{dK}{dS} = \frac{(s^2+16)(-2s-4)+(s^2+4s)(2s)}{(s^2+16)^2}$$

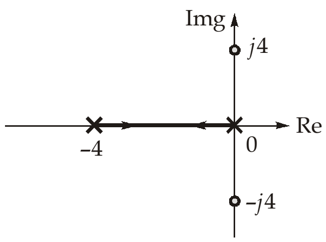
Putting, $$\frac{dK}{dS} = 0$$

We get, $$(s^2 + 16)(2s + 4) = (s^2 + 4s)\,(2s)$$

$\Rightarrow$ $$s^2 - 8s - 16 = 0$$

Solving above equation, we get

$$S_1, S_2 = -1.66,\ 9.65$$



As the point S = –1.66 lies on root locus, therefore this is valid breakaway point.

18. (d)

Check for controllability-

$$Q_C = [B : AB] = \begin{bmatrix} 0 \\ 1 \end{bmatrix} : \begin{bmatrix} 0 \\ -4 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 1 & -4 \end{bmatrix}$$

$\because$ $\rho(A) \neq \rho(Q_C)$

and $|Q_C| = 0$

$\therefore$ System is uncontrollable.

Check for observability,

$$Q_o = [C^T : A^T C^T]$$

$$= \begin{bmatrix} 1 \\ 0 \end{bmatrix} : \begin{bmatrix} -2 & 0 \\ 0 & -4 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 & -2 \\ 0 & 0 \end{bmatrix}$$

$\because$ $\rho(A) \neq \rho(Q_o)$

Also $|Q_o| = 0$

$\therefore$ System is unobservable.

19. (b)

The maximum phase provided by the compensator is,

$$\theta = \sin^{-1}\left(\frac{1-\alpha}{1+\alpha}\right) = 30°$$

$$\sin 30° = \frac{1-\alpha}{1+\alpha}$$

$$\frac{1}{2}(1+\alpha) = (1 - \alpha)$$

or $$\frac{3}{2}\alpha = \frac{1}{2}$$

or $$\alpha = \frac{1}{3}$$

$\because$ $\alpha\tau = 0.18$

$\therefore$ $$\tau = \frac{0.18}{\alpha} = \frac{0.18}{1/3} = 0.54 \text{ sec}$$

20. (d)

Characteristic equation,

$$\text{CE} = 1 + G(s)H(s) = 0$$

$$= 1 + \frac{3\alpha}{s^3 + 5s^2 + 2s + 1} = 0$$

or, $s^3 + 5s^2 + 2s + (3\alpha + 1) = 0$

Using Routh's tabular form,

s^3	1	2
s^2	5	$(3\alpha+1)$
s^1	$\dfrac{10-(3\alpha+1)}{5}$	0
s^0	$(3\alpha+1)$	

For system to have two poles at RHS,

$$10 - (3\alpha + 1) < 0$$

$$\Rightarrow \quad 10 < (3\alpha + 1)$$

$$9 < 3\alpha$$

$$\text{or} \quad \alpha > 3$$

21. (c)

Using Laplace transform of given response function, we get,

$$C(s) = \frac{1}{s} - \frac{1}{15(s+3)} + \frac{7}{(s+5)}$$

$$= \frac{15(s^2+8s+15) - s^2 - 5s + 95s^2 + 95s}{15s(s+3)(s+5)}$$

$$= \frac{109s^2 + 210s + 225}{15s(s+3)(s+5)}$$

$\therefore$ Transfer function,

$$T(s) = \frac{C(s)}{R(s)} = sC(s) = \frac{109s^2 + 210s + 225}{15(s+3)(s+5)}$$

$$\text{DC gain} = \lim_{s \to 0} T(s) = \frac{225}{15 \times 3 \times 5} = 1$$

22. (a)

The transfer function of the above circuit is,

$$\frac{E_0(s)}{E_i(s)} = \frac{R_2R_4(R_1C_1s+1)}{R_1R_3(R_2C_2s+1)} = \frac{R_4C_1}{R_3C_2}\left(\frac{s+\frac{1}{R_1C_1}}{s+\frac{1}{R_2C_2}}\right)$$

$$= K\alpha\left(\frac{1+sT}{1+\alpha sT}\right) = K_c\left(\frac{s+\frac{1}{T}}{s+\frac{1}{\alpha T}}\right)$$

Here, $T = R_1C_1$ and $\alpha T = R_2C_2$

If $R_1C_1 > R_2C_2$ then $\alpha < 1$.

Thus, it represents a phase lead network.

23. (c)

As the system is said to be stable,

Therefore, no open loop pole in the RHS.

$$\therefore \quad P = 0$$

The intersection point $\left(-\frac{4}{5}K, 0\right)$ and $K > \frac{5}{4}$.

$$\therefore \quad \frac{4}{5}K > 1$$

$$\text{or} \quad -\frac{4}{5}K < -1$$

That means the Nyquist plot encircles the critical point two times in the clockwise direction

Hence, $N = -2$

$\Rightarrow$ $N = P - Z$

$\Rightarrow$ $-2 = -Z$ or $Z = 2$

24. (b)

Let $K = 4$ then,

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

Characteristic equation = $1 + G(s)\,H(s) = s^2 + 4s + (4 + K) = 0$

Routh array
$$\begin{array}{c|cc} s^2 & 1 & (4+K) \\ s^1 & 4 & 0 \\ s^0 & 4+K & \end{array}$$

For stability $K > -4$

now, calculating ω_{pc}

$$-180° = 2\tan^{-1}\omega_{pc}$$

or $\omega_{pc} = \infty$

Hence $\text{GM} = 0 \text{ dB} = \infty$

and $$|G(\omega)H(\omega)| = \frac{4}{\left(\sqrt{(\omega_{gc})^2 + 2^2}\right)^2} = 1$$

$$\frac{4}{\left(\omega_{gc}^2 + 4\right)} = 1$$

or $\omega_{gc}^2 = 0$

$$\omega_{gc} = 0$$

$$\text{PM} = 180° - \tan^{-1}\frac{\omega_{gc}}{2} - \tan^{-1}\frac{\omega_{gc}}{2}$$

$$= 180°$$

25. (b)

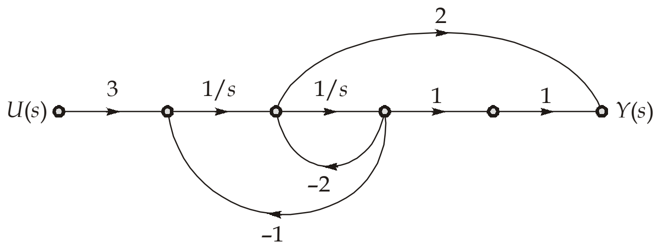
The state equation can be written as.

$$\dot{x}_1 = -2x_1 + x_2$$

$$\dot{x}_2 = -x_1 + 3u$$

and $y = x_1 + 2x_2$

$\therefore$ The signal flow graph corresponding to the state equations is



26. (c)

$$W_{BW} = \omega_n\sqrt{(1-2\xi^2)+\sqrt{4\xi^4-4\xi^2+2}}$$

$\because$ $$M_p = 20\% = e^{-\pi\xi/\sqrt{1-\xi^2}}\times 100$$

or $$e^{-\pi\xi/\sqrt{1-\xi^2}} = 0.2$$

$$\xi^2 = 0.262(1-\xi^2)$$

$$\xi^2 = 0.2078$$

$\Rightarrow \xi = 0.456 \approx 0.46$

and $$t_s = 2\,\text{sec} = \frac{4}{\xi\omega_n} \Rightarrow \xi\omega_n = 2 \Rightarrow \omega_n = 4.347\text{ rad/sec}$$

$\therefore$ $$W_{BW} = 4.347\sqrt{\sqrt{4(0.46)^4-4(0.46)^2+2}+(1-2(0.46)^2)}$$

$$= 4.347\sqrt{0.576+\sqrt{0.179-0.846+2}}$$

$$= 4.347\sqrt{1.73} = 5.72\text{ rad/sec}$$

27. (b)

Forward path gain, $P_1 = G_1$

$P_2 = G_1G_2$

Individual loop, $L_1 = -G_1H_1$

$L_2 = -G_1H_2$

$L_3 = -G_1G_2H_2$

$$\frac{x_5}{x_1} = \frac{P_1\Delta_1+P_2\Delta_2}{\Delta} = \frac{G_1(1+G_2)}{1+G_1H_1+G_1H_2+G_1G_2H_2}$$

$$\frac{x_5}{x_1} = \frac{2\times 6}{1+6+2H_2+10H_2}$$

$$\frac{3}{4} = \frac{12}{7+12H_2}$$

$$21 + 36H_2 = 48$$

$\Rightarrow$ $$H_2 = 0.75$$

28. (a)

Given, $$GH(s) = \frac{Ks+b}{s[s+(a-k)]}$$

The velocity error constant,

$$K_v = \lim_{s\to 0} sG(s)H(s) = \lim_{s\to 0}\frac{s(Ks+b)}{s(s+(a-k))}$$

$$= \frac{b}{a-k}$$

$\therefore$ the steady state error for a unit ramp input is

$$e_{ss}(t) = \frac{1}{K_v} = \frac{a-k}{b}$$

29. (a)

$$T = \frac{G}{1+GH}$$

also $$\frac{\partial G}{G} = 10\% = 0.1$$

$$S_G^T = \frac{\partial T}{T} \times \frac{G}{\partial G} = \frac{1}{1+GH}$$

or, $$\frac{\partial T}{T} = \frac{1}{21} \times 0.1 \times 100\%$$
$$= 0.476\%$$

30. (a)

The transfer function of the system is given by

$$\frac{Y(s)}{U(s)} = T(s) = C\,[sI - A]^{-1} B + D$$

$\therefore$ $$T(s) = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} s & -1 \\ 2 & s+3 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$= \frac{\begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} s+3 & 1 \\ -2 & s \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix}}{(s+1)(s+2)}$$

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

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