Serial No. : J_EC_A_090616_Control Systems

CLASS TEST - 2016

Electronics Engineering

EC

Control Systems

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ANSWERS

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

Explanation

1. (b)

Intersection with negative real axis is the magnitude at that frequency.

$$\therefore \quad -180° = -90° - 0.1 \times \frac{180°}{\pi} \times \omega_{pc}$$

$$\omega_{pc} = 15.7 \text{ rad/sec.}$$

$$\therefore \quad |M|_{\omega = \omega_{pc}} = \frac{\pi \times \left|e^{-j0.1\omega_{pc}}\right|}{\omega_{pc}} = 0.2$$

$\therefore$ So the intersection with negative real axis is –0.2

2. (a)

$$A = \begin{bmatrix} 0 & 2 \\ -2 & 0 \end{bmatrix}$$

for eigen values

$$|sI - A| = 0$$

$$\begin{vmatrix} s & -2 \\ 2 & s \end{vmatrix} = 0$$

$$s^2 + 4 = 0$$

$$s = \pm 2j$$

Poles on imaginary axis, therefore system is undamped.

3. (c)

$$P = 12 \;;\; z = 4$$

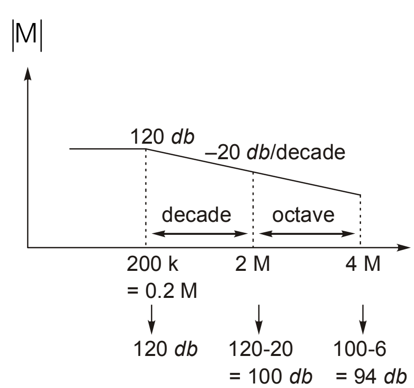
So highest slope

$$= -20\,(p - z) = -20 \times (12 - 4)$$

$$= -20 \times 8 = -160 \; db/\text{decade}$$

4. (d)

Since the bode plot will be as



As 20db/decade = 6db/octave

5. (d)

s^3	2	2
s^2	4	4
s^1		0
s^0	4	

$$A(s) = 4s^2 + 4 = 0$$
$$s = -1$$
$$s = \pm j$$

No sign change.

6. (a)

$$\frac{k}{s+1} + 1 = \frac{k+s+1}{s+1}$$
$$k = 1$$

7. (a)
Only (a) is a valid root loci since in (b), (c) and (d) the root loci lies to the left of an even number of zeros and poles. Hence option (a) is correct.

8. (c)
The location of the poles (i.e., the points at which the root locus starts) are at $s = 0$ and $s = -1$. The location of the zero (i.e., the points at which the root locus ends) are at $s = -2$ and $s = -\infty$.

Hence, $$G(s) = \frac{K(s+2)}{s(s+1)}$$

9. (d)
"It is immune to instability" is the incorrect statement.

10. (a)
For stability the dB value of gain should be negative. After adding +5 dB, gain is still negative,

$$GM = \frac{1}{|GH|} \text{ or } 20 \log \frac{1}{|GH|} = -20 \log |GH|$$

So as log it is negative. |GH| is always less than 1 so that GM becomes positive.

11. (c)
From the equations, we have

$$[A] = \begin{bmatrix} -1 & 0 \\ 0 & -2 \end{bmatrix} \qquad [B] = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$
$$[C] = [1, 2] \qquad [D] = [0]$$

Check for Controllability:

$$[AB] = \begin{bmatrix} -1 & 0 \\ 0 & -2 \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ -2 \end{bmatrix}$$

$$[B\ AB] = \begin{bmatrix} 0 & 0 \\ 1 & -2 \end{bmatrix}$$

Whose determinant is zero. Hence the system is not controllable.
Test for Observability:

$$[C] = [1 \;\; 2]$$

$$[CA] = [1 \;\; 2]\begin{bmatrix} -1 & 0 \\ 0 & -2 \end{bmatrix} = [-1 \; -4]$$

Hence, $$\begin{bmatrix} C \\ CA \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ -1 & -4 \end{bmatrix}$$

The determinant $\Delta = \begin{bmatrix} 1 & 2 \\ -1 & -4 \end{bmatrix} = -2 \neq 0$

Hence the system is completely observable.

Hence choice (c) is correct.

12. (b)

Since the slope of the plot at the origin is zero, there are no poles at the origin. The only corner frequency is at

$$\log_{10}\omega = 1;$$

$\Rightarrow$ $$\omega = 10 \text{ rad/sec}$$

Hence, $$G(s) = \frac{K}{s+10}$$

At initial slope,`

$$20 \log (K) = 20;$$

$\Rightarrow$ $$K = 10$$

Hence, $$G(s) = \frac{10}{\left(\frac{s}{10}+1\right)} = \frac{100}{(s+10)}$$

13. (c)

The characteristic equation is

$$1+\left(\frac{s-5}{s+4}\right).K = 0$$

$$(s+4) + K(s-5) = 0$$

$$s(1+K) + (4-5K) = 0$$

$$\begin{array}{c|c} S^1 & 1+K \\ S^0 & 4-5K \end{array}$$

$$4 - 5K \geq 0$$

$$5K \leq 4$$

$\Rightarrow$ $$K \leq \frac{4}{5}$$

14. (b)

The state equations can be written as

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} e \\ e \end{bmatrix}u(t)$$

Since, $$x_1(t) = x_2(t);$$

$$a + b = c + d$$

The controllability matrix is

$$\phi = [B\ AB]; \qquad B = \begin{bmatrix} e \\ e \end{bmatrix} \text{ and}$$

$$AB = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} e \\ e \end{bmatrix} = \begin{bmatrix} (a+b)e \\ (c+d)e \end{bmatrix}; \qquad \phi = \begin{bmatrix} e & (a+b)e \\ e & (c+d)e \end{bmatrix}$$

Let $\qquad |\phi| = e^2(c+d) - e^2(a+b) = 0$

Since $\qquad a + b = c + d.$

Hence the system is uncontrollable. We cannot say anything further about the stability or observability of the system. Hence choice (b) is correct.

15. (c)

s^3	1	4
s^2	3	A
s^1	$\frac{12-A}{3}$	0
s^0	A	

$$12 - A > 0$$
$$A < 12 \text{ and } A > 0$$
$$0 < A < 12$$

16. (b)

$$\text{Initial} = -40 \text{ dB/decade}$$

Hence, $\qquad -20\text{ N} = -40$

Type of the system, $\qquad N = 2$

For type 2 system;

steady state error for

(a) step input $e_{ss} = 0$

(b) ramp input $e_{ss} = 0$

for (c) Parabolic input $e_{ss} = \dfrac{1}{K_a}$

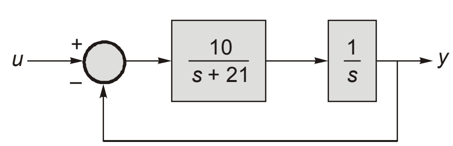
and $\qquad K_a = \lim_{s\to 0} s^2 G(s) = \text{finite}$

17. (a)

From figure (a)

Eliminating first loop

$$\frac{y}{u} = \frac{\frac{10}{s(s+21)}}{1+\frac{10}{s(s+21)}} = \frac{10}{s^2+21s+10}$$



For the figure (b) $$\frac{y}{u} = \frac{\frac{10}{s(s+1)}}{1+\frac{10}{s(s+1)}\times H} = \frac{10}{s^2+s+10H}$$

Comparing, $$s^2 + 21s + 10 = s^2 + s + 10H,$$
$$10H = 20s + 10,$$
$$H = 2s + 1$$

18. (d)
From log -magnitude plot,
corner frequency at $\log \omega = -1;$
or $\omega = 0.1;$
Hence pole at $\omega = 0.1,$
and gain; $\log |G| = 1,\ G = 10,$

Hence transfer fuction $$TF = \frac{10}{(1+s/0.1)} = \frac{1}{s+0.1}$$

19. (d)
Centroid, $\sigma = -2$
Break away point = -2. In choice (c), break away point is between 1 and 2 and centroid = -2.

20. (b)
Transportation lag causes instability in a system.

21. (b)
At $\omega = 0$, $M = \infty$, $\phi = -90°$. So there is a pole at origin.

So, TF will be = $\left(\frac{1+sT}{s}\right)$

The addition of a zero pulls high frequency portion of the polar plot in the counter clockwise direction. Hence, pole is nearer to origin than zero.

22. (c)
T_D the delay time, is not a desirable feature. It is the time taken by the system before starting to respond. Hence. T_S/T_D cannot be less than 1 as the system is unstable in this case. So the ratio T_S/T_D should be made as large as possible to make the sytem controllable.Therefore, the answer at (c) (greater than 10) is appropriate.

23. (d)
$$(s + 3 + j4)(s + 3 - j4) = 0$$
$$(s + 3)^2 - (j4)^2 = 0;\ s^2 + 6s + 9 + 16 = 0;\ s^2 + 6s + 25 = 0$$
$$\omega_n = \sqrt{25};\quad \omega_n = 5 \text{ rad/sec};\quad 2\zeta\omega_n = 6$$
$$\zeta = \frac{6}{2\times 5} = 0.6$$

24. (c)
$\because$ $$y(t) = AM \sin(2t + \phi)$$

Where, $$A = 2,\ \&\ M = \left|\frac{1}{j\omega + 2}\right|$$

At $\omega = \quad M = \dfrac{1}{2\sqrt{2}}$

and $\phi = -\tan^{-1}\left(\dfrac{\omega}{2}\right) = -\tan^{-1}(1/1) = -45° = -\pi/4$

$$y(t) = \frac{1}{\sqrt{2}}\sin(2t - \pi/4)$$

25. (a)

$$G(s) = \frac{1}{sT_1(1+sT_2)}$$

$$TF = \frac{\dfrac{1}{sT_1(1+sT_2)}}{1+\dfrac{1}{sT_1(1+sT_2)}} = \frac{1}{sT_1(1+sT_2)+1} = \frac{1}{s^2T_1T_2+sT_1+1}$$

$$= \frac{1}{T_1T_2\left(s^2+\dfrac{s}{T_2}+\dfrac{1}{T_1T_2}\right)}$$

$$\omega_n = \frac{1}{\sqrt{T_1T_2}};$$

$$\xi = \frac{1}{2}\sqrt{\frac{T_1}{T_2}}$$

for $\xi << 1$, $\Rightarrow$ $T_1 << T_2$

26. (d)

From plot, initial slope $= \dfrac{(60-0)\,\text{dB}}{-2-1} = -20$ dB / decade

Hence type = 1

and pole at $\omega = 0.05$, zero at $\omega = 0.1$

Hence $T(s) = \dfrac{K(1+s/0.1)}{s(1+s/0.05)}$

From initial slope line equation

$$60 \text{ dB} = 20\log K - 20\log\omega$$

At $\omega = 0.01$ $\quad 60 = 20\log K - 20\log(0.01)$

$\Rightarrow$ $\quad K = 10$

Now $T(s) = \dfrac{10(1+s/0.1)}{s(1+s/0.05)} = \dfrac{5(s+0.1)}{s(s+0.05)}$

27. (a)

Zeros $\quad s = -2$

Poles: $\quad s = -1 + j2, -1 - j2$

The transfer function is

$$G(s) = \frac{K(s+2)}{(s+1-j2)(s+1+j2)}$$

where $$K = \frac{\text{multiplication of vector lengths drawn from all poles}}{\text{multiplication of vector lengths drawn from all zeros}}$$

$$= \frac{\sqrt{10} \times \sqrt{2}}{\sqrt{5}} = 2$$

$$G(s = j1) = \frac{2(j1+2)}{(j1+1-j2)(j1+1+j2)} = \frac{2(2+j1)}{(1-j1)(1+j3)}$$

$$= \frac{2 \times 2.236\angle 26.6^\circ}{1.4142\angle -45^\circ \times 3.162\angle 71.57^\circ} = 1\angle 0^\circ$$

Hence choice (a) is correct.

28. (b)

Characteristic equation

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

$$\Rightarrow \quad 1 + \frac{11\beta}{s^3 + 4s^2 + 3s + 1} = 0$$

or, $s^3 + 4s^2 + 3s + 1 + 11\beta = 0$

Routh array

s^3	1	3
s^2	4	$(11\beta + 1)$
s^1	$\frac{12-(11\beta+1)}{4}$	0
s^0	$(11\beta + 1)$	

for stability,

$$\frac{12-(11\beta+1)}{4} \geq 0$$

or $$12 \geq (11\beta + 1)$$

or $$\beta \leq 1$$

29. (b)

The transfer function for the given block diagram is

$$\frac{C(s)}{R(s)} = \frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)H(s)} + \frac{N(s)G_2(s)}{1+G_1(s)G_2(s)H(s)} = \frac{G_1(s)G_2(s)\left(1+\frac{N(s)}{G_1(s)}\right)}{1+G_1(s)G_2(s)H(s)}$$

Thus, In order to reduce the effect of noise element the gain $G_1(s)$ should be increased.

30. (d)

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

Also, $$26\,\text{dB}\big|_{\omega=0.1} = 20\log K - 20\log\omega$$

or $$K = 2$$

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