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Electronics Engineering

CLASS TEST
2016

EC

Control Systems

Date : 02/09/2016

ANSWERS

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

Explanation

1. (b)

$$\frac{d}{dt}[\text{step response}] = \text{impulse response}$$

$$\frac{d}{dt}[c(t)] = h(t)$$

$$h(t) = 0 + 3e^{-3t} - 3e^{-t}$$

$$h(t) = 3(e^{-3t} - e^{-t})$$

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

$$H(s) = \frac{-2}{(1+s)\left(1+\frac{s}{3}\right)}$$

$$\text{Gain} = -2$$

2. (c)

$$GM\,(dB) = 6\text{ dB} = 20\log_{10} GM$$

$$GM = 2$$

$$K_{marginal} = 40$$

We know $GM = \frac{K_{(marginal)}}{K_{(desired)}}$

$$K_{desired} = \frac{40}{2} = 20$$

3. (c)

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

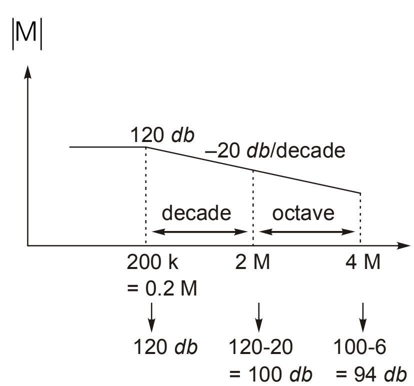
So highest slope

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

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

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. (d)

2^{nd} order characterisics equation $s^2 + 2\xi\omega_n s + \omega_n{}^2 = 0$ have poles at $-\xi\omega_n \pm j\omega_d$

On comparing we have

$$-1 \pm j\pi$$
$$\omega_d = \pi$$

$$\Rightarrow \quad t_p = \text{peak time} = \frac{\pi}{\omega_d} \text{ (first peak)}$$

$$= \frac{\pi}{\pi} = 1\,\text{sec.}$$

7. (c)

Approximation of second order system

$$= \frac{60/44.4 \times 44.4}{s^2 + 2.45s + 44.4} = 0 = \frac{k.\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$\omega_n = \sqrt{44.4} = 6.66 \text{ rad/sec}$$

$$\zeta\omega_n = \frac{2.45}{2}$$

$$\zeta = \frac{2.45}{2 \times 6.66} = 0.183$$

$$M_{PO} = e^{-\pi\zeta/\sqrt{1-\zeta^2}} = 0.557$$

$$\Rightarrow \quad K \times M_{PO} = \frac{60}{44.5} \times 0.557$$

$$\% M_{PO} = 75.3 \approx 75$$

8. (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

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

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

$\Rightarrow$ $\omega = 10$ rad/sec

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

At initial slope,`

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

$\Rightarrow$ $K = 10$

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

13. (b)

$$\text{The OLTF} = \frac{K(s+3)}{s(s+1)}; \text{ here } b = 3; a = 1$$

$$\text{radius} = \sqrt{b(b-a)} = \sqrt{3(3-1)} = \sqrt{6}$$

centre = (–b, 0) = (–3, 0)

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

Since $a + b = c + d.$

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)

$$\begin{array}{c|cc} s^3 & 1 & 4 \\ s^2 & 3 & A \\ s^1 & \dfrac{12-A}{3} & 0 \\ s^0 & A & \end{array}$$

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

16. (b)

Initial = –40 dB/decade

Hence, $-20\,N = -40$

Type of the system, $N = 2$

For type 2 system;

steady state error for

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

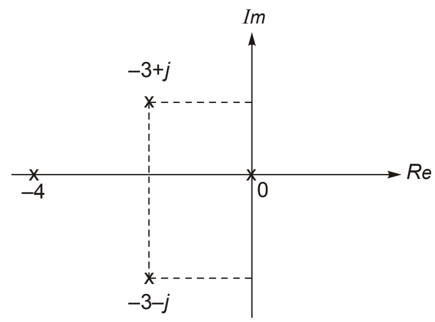
(b) ramp input $e_{ss} = 0$

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

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

17. (b)

$\phi_d = \ldots\ldots \phi$



$$\phi = 90° + 45° + 161.565° = 296.56°$$

$$\therefore \quad \phi_d = 180° - 296.5650 = \mp 116.56°$$

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. (c)

The state transition matrix

$$\phi(s) = (sI - A)^{-1}$$

or $(sI - A) = [\phi(s)]^{-1}$

$$\begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - [A] = [\phi(s)]^{-1}$$

$$= \begin{bmatrix} s & -1 \\ 5 & s+6 \end{bmatrix}$$

or $[A] = \begin{bmatrix} 0 & 1 \\ -5 & -6 \end{bmatrix}$

22. (b)

$$\frac{d^2y}{dt^2} + 3\frac{dy}{dt} + 2y = x(t)$$

$$s^2 Y(s) + 3s\,Y(s) + 2\,Y(s) = X(s)$$

$$x(t) = 2\,u(t)$$

$$X(s) = \frac{2}{s}$$

$\therefore$

$$(s^2 + 3s + 2)\,Y(s) = \frac{2}{s}$$

$$Y(s) = \frac{2}{s(s+2)(s+1)} = \frac{A}{s} + \frac{B}{s+2} + \frac{C}{s+1}$$

using partial fraction, we get

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

taking inverse Laplace transform

$$y(t) = [1 + e^{-2t} - 2e^{-t}]\,u(t)$$

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

$$\omega = 2,\ M = \frac{1}{2\sqrt{2}}$$

and

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

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

25. (a)

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

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

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

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

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

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

26. (c)

standard form $c(t) = 1-\frac{e^{-\xi\omega_n}}{\sqrt{1-\xi^2}}\cdot\sin(\omega_d t+\theta)$

where, $\theta = \cos^{-1}\xi = \tan^{-1}\frac{\sqrt{1-\xi^2}}{\xi}$

or $\xi = 0.6$

Here, $\xi\omega_n = 6$

$\therefore$ $\omega_n = 10$ rad/sec

27. (a)

Zeros $s = -2$

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

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,

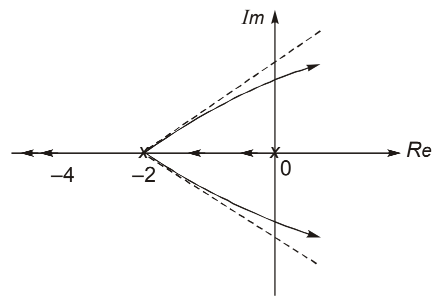
$$\frac{12-(11\beta+1)}{4} \geq 0$$

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

or $\beta \leq 1$

29. (b)

Approximated root locus for the given transfer function



Intersection with imaginary axis:

characteristic equation

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

or $$K = 48$$

Auxiliary equation

$$6s^2 + K = 0$$

or $$\omega = \sqrt{8}j = \pm 2.8j$$

30. (c)

characteristic equation ⇒ $$|sI - A| = 0$$

$$\begin{vmatrix} s & -1 \\ -6 & s+5 \end{vmatrix} = 0$$

$$= s(s+5) - 6 = 0 \quad \text{or} \quad s = +1 \text{ and } -6$$

∴ One pole is located at RHS, hence, unstable

Check for controllability

$$Q_C = [B : AB]$$

$$= \begin{bmatrix} 0 & 1 \\ 1 & -5 \end{bmatrix}$$

∵ $$|Q_C| \neq 0$$

and $$\text{Rank } \rho(A) = \text{Rank } \rho(Q_C)$$

∴ controllable

Check for observability

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

$$= \begin{bmatrix} 6 & 6 \\ 1 & 1 \end{bmatrix}$$

∵ $$\rho(A) \neq \rho(Q_O)$$

also $$|Q_O| = 0$$

∴ unobservable

■■■■