OFFLINE TEST SERIES

MADE EASY

India's Best Institute for IES, GATE & PSUs

ESE-2017 : Prelims Exam

UPSC Engineering Services Examination

E & T ENGINEERING

Answer Key & Solutions

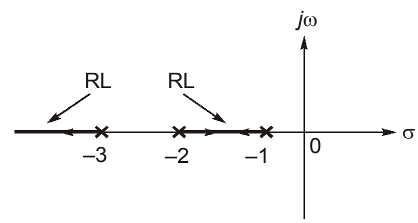
Test 5: Part Syllabus Technical

Control Systems

1.	(b)	16.	(c)	31.	(a)	46.	(d)	61.	(d)
2.	(a)	17.	(d)	32.	(b)	47.	(d)	62.	(c)
3.	(c)	18.	(b)	33.	(c)	48.	(a)	63.	(a)
4.	(b)	19.	(d)	34.	(d)	49.	(d)	64.	(b)
5.	(d)	20.	(a)	35.	(b)	50.	(c)	65.	(b)
6.	(b)	21.	(c)	36.	(b)	51.	(a)	66.	(c)
7.	(a)	22.	(c)	37.	(a)	52.	(c)	67.	(c)
8.	(d)	23.	(c)	38.	(a)	53.	(d)	68.	(a)
9.	(b)	24.	(a)	39.	(a)	54.	(c)	69.	(b)
10.	(d)	25.	(d)	40.	(a)	55.	(a)	70.	(a)
11.	(c)	26.	(a)	41.	(b)	56.	(b)	71.	(a)
12.	(c)	27.	(d)	42.	(d)	57.	(c)	72.	(a)
13.	(b)	28.	(a)	43.	(b)	58.	(d)	73.	(a)
14.	(a)	29.	(c)	44.	(c)	59.	(b)	74.	(a)
15.	(b)	30.	(d)	45.	(c)	60.	(d)	75.	(a)

DETAILED EXPLANATIONS

1. (b)



2. (a)

$$\dot{x}(t) = -2x(t) + 2u(t)$$
$$y(t) = 0.5\,x(t)$$

Taking Laplace transform, we get

$$sX(s) = -2X(s) + 2U(s)$$

or $$X(s)\,[s+2] = 2U(s) \quad \text{...(i)}$$

also $$Y(s) = 0.5\,X(s) \quad \text{...(ii)}$$

from (i) and (ii)

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

3. (c)

Number of RL branches terminate at infinity = $P - Z$

$$= 5 - 3 = 2$$

4. (b)

The transfer function of the system is

$$G(s)\,H(s) = \frac{Ks^2}{\left(\frac{s}{P_1}+1\right)\left(\frac{s}{P_2}+1\right)\left(\frac{s}{P_3}+1\right)}$$

∴ the phase angle

$$\angle G(j\omega)\,H(j\omega) = 90^\circ \times 2 - \tan^{-1}\frac{\omega}{P_1} - \tan^{-1}\frac{\omega}{P_2} - \tan^{-1}\frac{\omega}{P_3}$$

at $\omega = 0$; $\angle G(j\omega)\,H(j\omega) = 180^\circ$

at $\omega = \infty$; $\angle G(j\omega)\,H(j\omega) = 180^\circ - 90^\circ - 90^\circ - 90^\circ = -90^\circ$

Thus, the function will be monotonically decreasing from 180° to –90°.

5. (d)

The open loop transfer function

$$G'(s) = G(s)\,G_c(s)$$
$$= \frac{T_p(1+T_D s)}{s^2}$$

As it represents type 2 system

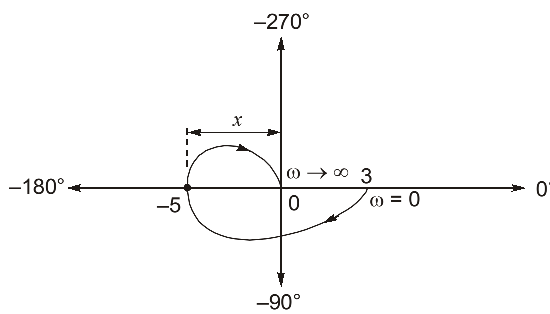
Thus, it has finite steady state error for a unit parabolic input.

6. (b)

At each corner frequency, the slop changes are

$$+40 \text{ dB/sec} = 2 \text{ zeros}$$
$$-20 \text{ dB/sec} = 1 \text{ pole}$$
$$+40 \text{ dB/sec} = 2 \text{ zeros}$$
$$-60 \text{ dB/sec} = 3 \text{ poles}$$
$$-40 \text{ dB/sec} = 2 \text{ poles}$$
$$-20 \text{ dB/sec} = 1 \text{ pole}$$
$$+40 \text{ dB/sec} = 2 \text{ zeros}$$

7. (a)



$$\text{Gain margin} = \frac{1}{|x|} = \frac{1}{5} = 0.2$$

8. (d)

$$\text{poles} = 0, +1$$
$$\text{zero} = -1$$

∴ characteristic equation $1 + \frac{K(s+1)}{s(s-1)} = 0$

or $K = -\frac{s(s-1)}{(s+1)}$

The break point

$$\frac{dK}{ds} = 0$$

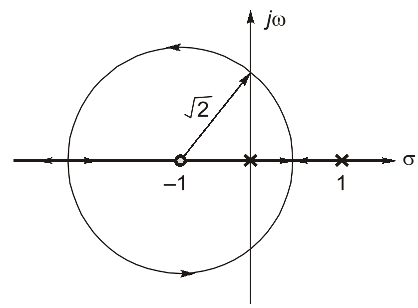
$$\frac{d}{ds}\left\{\frac{-s(s-1)}{(s+1)}\right\} = 0$$

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

$$s^2 + 2s - 1 = 0$$

or $s = -1 \pm \sqrt{2}$

∴ The root locus will be



from root locus, we get

$$\text{center} = (-1, 0)$$

$$\text{radius} = \sqrt{2}$$

11. **(c)**

The state transition matrix is given by

$$e^{At} = L^{-1}[sI - A]^{-1}$$

12. **(c)**

Second order system has the standard transfer function as

$$T(s) = \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

∴ the open loop transfer function $= \dfrac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2 - \omega_n^2}$

or

$$G(s)\,H(s) = \frac{\omega_n^2}{s(s + 2\xi\omega_n)}$$

$$K_v = \lim_{s \to 0} s \times G(s)H(s)$$

$$K_v = \frac{\omega_n^2}{(s + 2\xi\omega_n)} = \frac{\omega_n}{2\xi}$$

$$e_{ss} = \frac{1}{K_v} = \frac{2\xi}{\omega_n}$$

14. **(a)**

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

$$= \lim_{s \to 0} \frac{4(1 + 2s)}{s(s + 2)} = \infty$$

$$e_{ss} = \frac{1}{\infty} = 0$$

Note : For type-2 system, unit ramp input results in zero steady state error.

16. (c)

The phase cross over frequency is given by

$$\angle G(j\omega)\,H(j\omega)\,|_{\omega=\omega_{pc}} = -180^\circ$$

$$-180^\circ = -90^\circ - \tan^{-1}\frac{0.2\,\omega_{pc}}{1} - \tan^{-1}\frac{0.05\,\omega_{pc}}{1}$$

$$-90^\circ = -\tan^{-1}\left\{\frac{0.2\,\omega_{pc} + 0.05\,\omega_{pc}}{1-(0.2\times 0.05)\,\omega_{pc}^2}\right\}$$

$$\tan 90^\circ = \frac{0.25\,\omega_{pc}}{1-0.01\,\omega_{pc}^2}$$

or $$1-0.01\,\omega_{pc}^2 = 0$$

or $$\omega_{pc}^2 = \frac{1}{0.01}$$

or $$\omega_{pc} = \sqrt{100} = 10 \text{ rad/sec}$$

17. (d)

The centroid of a root locus is given by

$$= \frac{\Sigma P - \Sigma Z}{(P-Z)}$$

Going through all the options

(a) $\frac{-2-1+0}{3} = -1$

(b) $\frac{-1-3+2}{3} = -\frac{2}{3}$

(c) $\frac{-1-2-3}{3} = -2$

(d) $\frac{-2-2-2}{3} = -2$

$\Rightarrow$ Finding breakaway point for option (d),

$$k = -(s^3 + 6s^2 + 12s + 8)$$

$$\frac{dK}{ds} = 0 \quad \Rightarrow \quad s = -2$$

only option (d) satisfies.

18. (b)

The loop transfer function of the system is

$$G(s)\,H(s) = \frac{-9}{s(s+3)} \times \frac{s^2}{9} = -\frac{s}{(s+3)}$$

The closed loop transfer function

$$T(s) = \frac{\frac{9}{s(s+3)}}{1-\frac{s}{(s+3)}} = \frac{3}{s}$$

21. (c)

The standard form of a compensator is $\frac{1+s\tau}{1+\alpha s\tau}$

$$\therefore \qquad G(s) = \frac{2\times 4(2s+1)}{(6s+1)}$$

here $\tau = 2$

and $\alpha\tau = 6$

$\therefore$ $\alpha = 3$

$\because$ $\alpha > 1$, lag compensator

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

$$= \sin^{-1}\left(\frac{1}{2}\right) = 30°$$

22. (c)

Total number of poles = 4 (at 0, −2, −1 ± j)

Total number of zeros = 1 (at − 1)

$\therefore$ Total number of zeros located at infinity

$$P - Z = 4 - 1 = 3$$

24. (a)

By Nyquist criterion, for system to be stable

$$N = P - Z \; ;$$

here P = number of open loop poles at RHS of s-plane = 1

N = number of encirclements to the critical point

Z = number of closed loop poles at RHS of s-plane

- so we can eliminate options (c) and (d)
- CE : $1 + G(s)\,H(s) = 0$

$$s^2 + s + 1 = 0 \qquad \Rightarrow \text{ stable}$$

- as the closed loop system is stable, $Z = 0$

$$N = P - Z$$

- as $P = 1$, N must be 1
- for option (a) $\Rightarrow N = 1$

for option (b) $\Rightarrow N = -1 \Rightarrow$ so option (a) is the correct one.

27. (d)

The open loop transfer function $G(s)\,H(s) = \frac{4}{(s^2+2s+2)}\times\frac{(s-1)}{(s+1)}$

No poles at RHS of s-plane thus stable

The closed loop transfer function $T(s) = \dfrac{G(s)}{1+G(s)H(s)}$

$$T(s) = \frac{\dfrac{4}{(s^2+2s+2)}}{1+\dfrac{4(s-1)}{(s+1)(s^2+2s+2)}} = \frac{4(s+1)}{(s+1)(s^2+2s+2)+4(s-1)}$$

$$= \frac{4(s+1)}{s^3+2s^2+2s+s^2+2s+2+4s-4}$$

$$T(s) = \frac{4(s+1)}{s^3+3s^2+8s-2}$$

Using Routh's tabular form

$$\begin{array}{c|cc} s^3 & 1 & 8 \\ s^2 & 3 & -2 \\ s^1 & \dfrac{24+2}{3} & 0 \\ s^0 & -2 & \end{array}$$

As the number of sign changes in the first column of Routh's form is 1, the closed loop system is unstable.

28. (a)

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

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

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

Using Routh's tabular form

$$\begin{array}{c|cc} s^3 & 1 & 3 \\ s^2 & 4 & (11\beta+1) \\ s^1 & \dfrac{12-(11\beta+1)}{4} & 0 \\ s^0 & (11\beta+1) & \end{array}$$

For system to be stable

$$11\,\beta + 1 > 0$$

or $\quad \beta > -\dfrac{1}{11}$

and $\quad 12-(11\beta + 1) > 0$

$$11\beta + 1 < 12$$

or $\quad \beta < 1$

29. (c)

characteristic equation ⇒ $2s^4 + s^3 + 3s^2 + 5s + 10 = 0$

s^4	2	3	10
s^3	1	5	0
s^2	$\frac{3-10}{1}$	10	0
s^1	$\frac{-45}{-7}$	0	0
s^0	10		

As the number of sign changes in the first column of Routh's array is 2, two poles lie in the RHS of s-plane.

30. (d)

$$(s + 3 + j4)\,(s + 3 - j4) = 0$$

$$(s + 3)^2 - (j4)^2 = s^2 + 6s + 25$$

by comparing it with standard characteristic equation,

$$\omega_n^2 = 25\ (\text{rad/sec})^2$$

or $$\omega_n = \sqrt{25} = 5\ \text{rad/sec}$$

and $$2\xi\omega_n = 6$$

or $$\xi = \frac{6}{2\times 5} = 0.6$$

31. (a)

$$\text{settling time} \propto \frac{1}{\xi\omega_n}$$

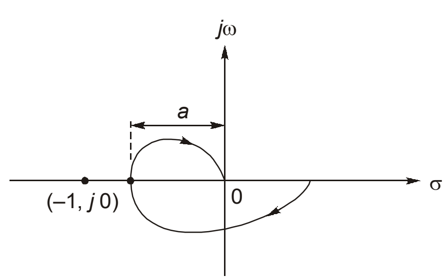
for system 1: $2\xi\omega_n = 5 \Rightarrow \xi\omega_n = 2.5$

for system 2: $2\xi\omega_n = 4 \Rightarrow \xi\omega_n = 2$

for system 3: $2\xi\omega_n = 3.6 \Rightarrow \xi\omega_n = 1.8$

- large value of $\xi\omega_n$ indicates small settling time.
- Hence, option (a) is correct.

32. (b)



GM = 20 log (1/a)

for $a < 1$, GM > 0 dB

for $a = 1$, GM = 0 dB

for $a > 1$, GM < 0 dB

33. (c)

$$\text{Phase angle} = -\tan^{-1}\left(\frac{\omega}{1}\right) - 57.3° \times 0.1$$

$$= -\tan^{-1}(1) - 5.73° \qquad (\because r(t) = 0.5\cos t,\ \therefore \omega = 1 \text{ rad/sec})$$

$$= -45° - 5.73°$$

$$= -50.73°$$

34. (d)

The eigen value of state matrix is

$$|sI - A| = 0$$

$$\begin{vmatrix} s+2 & 0 \\ 1 & s+1 \end{vmatrix} = 0$$

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

or $s = -2, -1$

$\therefore$ The eigen value of the system having state vector $[A]^{-1} = -\frac{1}{2}$ & -1

35. (b)

The characteristic equation of the closed loop system is

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

here $$G(s) = \frac{K}{s(s+4)(s+5)}$$

and $H(s) = 1$

$\therefore$ $s(s + 4)(s + 5) + K = 0$

or $s^3 + 9s^2 + 20s + K = 0$

using Routh's tabular form

s^3	1	20
s^2	9	K
s^1	$\frac{180-K}{9}$	0
s^0	K	

for stability of the system

$$\frac{180-K}{9} > 0$$

or $K < 180$ and $K > 0$

36. (b)

The unit impulse response of the system

$$H(s) = \frac{C(s)}{R(s)} = L[4e^{-2t}u(t)]$$

$$H(s) = \frac{4}{(s+2)}$$

for
$$R(s) = L[e^{-t}u(t)] = \frac{1}{s+1}$$

$$C(s) = H(s)\,R(s)$$

$$= \frac{4}{(s+2)} \times \frac{1}{(s+1)}$$

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

37. (a)

$\beta_0 = 0,\ \beta_1 = 3,\ \beta_2 = 2,\ \alpha_1 = 7,\ \alpha_2 = 9$

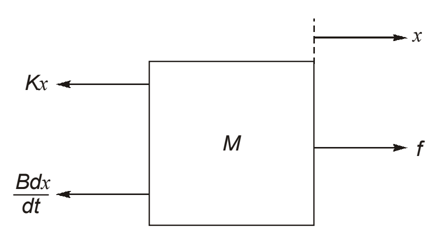
$$A = \begin{bmatrix} 0 & 1 \\ -\alpha_2 & -\alpha_1 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -9 & -7 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$C = [\beta_2 - \alpha_2\beta_0 \ \ \beta_1 - \alpha_1\beta_0]$$
$$= [2 \quad 3] \quad d = \beta_0 = 0$$

38. (a)

This is a second order differential equation which means that there must be present all the three components in the system, i.e. either R, L and C or K, B and M.



Free body diagram of M in fig. 1

In Figure 1,

$$f - Kx - B\frac{dx}{dt} = M\frac{d^2x}{dt^2}$$

or
$$M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx = f \qquad ..(i)$$

In Figure 2,

$$v(t) = Ri + \frac{Ldi}{dt} + \frac{q}{c}$$

or $$v(t) = \frac{Ld^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{c} \quad \text{...(ii)}$$

Both the equations are similar to the given equation.

39. (a)

The open loop transfer function of the given system

$$G(s)\,H(s) = \frac{(2s+5)(s+2)}{s^4(s+3)(s+1)}$$

The system represents type-4 system.

40. (a)

The closed loop transfer function is given by

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

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

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

Using Routh's tabular form

$$\begin{array}{c|cc} s^2 & 1 & 1 \\ s^1 & 1 & 0 \\ s^0 & 1 & \end{array}$$

As there is no sign change in the first column of Routh table the system is said to be stable.

41. (b)

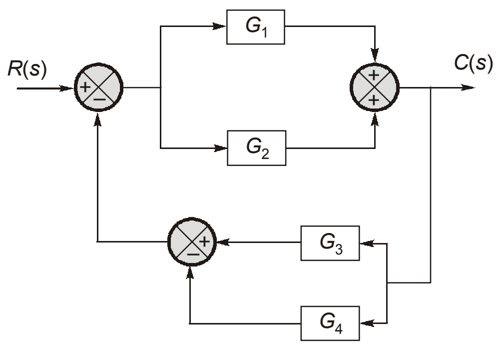
The closed loop transfer function

The sensitivity of the system with respect to the feedback gain

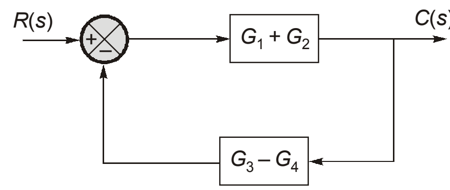
$$S_H^T = \frac{-G(s)H(s)}{1+G(s)H(s)}$$

$$= \frac{\frac{-11}{s}}{1+\frac{11}{s}} = \frac{-11}{(s+11)}$$

42. (d)

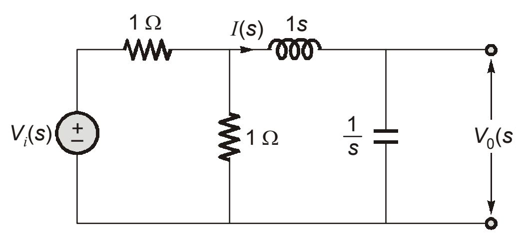


⇒



$$\frac{C(s)}{R(s)} = \frac{G_1 + G_2}{1 + (G_1 + G_2)(G_3 - G_4)}$$

43. (b)



$$V_0(s) = \frac{1}{s} I(s) \qquad \text{...(i)}$$

$$I(s) = \frac{V_i(s)}{\dfrac{\left(s+\frac{1}{s}\right)\times 1}{\left(s+\frac{1}{s}\right)+1} + 1} \times \frac{1}{1+s+\frac{1}{s}} \qquad \text{(using current division rule)}$$

$$= \frac{V_i(s)}{\dfrac{2s^2+s+2}{s^2+s+1}} \times \frac{s}{s^2+s+1}$$

$$= \frac{s}{2s^2+s+2} V_i(s)$$

from (i)

$$V_0(s) = \frac{1}{s} \times \frac{s}{2s^2+s+2} V_i(s)$$

⇒

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{2s^2+s+2}$$

45. (c)

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

$$1+\frac{K(Ts+1)}{s(s+2)} = 0$$

$$s^2 + (2 + KT)s + K = 0 \quad \text{...(i)}$$

from the given data

$$\text{characteristic equation} = (s + 2 + j2)\,(s + 2 - j2) = 0$$

$$s^2 + 4s + 8 = 0 \quad \text{...(ii)}$$

on comparing (i) and (ii)

$$K = 8$$

$$2 + KT = 4$$

$$\Rightarrow \quad T = \frac{1}{4}$$

46. (d)

Steady state error for unit step input is given by

$$e_{ss} = \frac{1}{1+K_p}$$

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

$$\because \quad e_{ss} = 0.2 \text{ [for unit step]}$$

$$0.2 = \frac{1}{1+K_p}$$

$$\therefore \quad K_p = 4$$

$$\Rightarrow \quad \lim_{s\to 0} G(s) = 4$$

Now for modified system

$$G'(s) = \frac{1}{s}G(s)$$

$\because$ Steady state error for unit ramp input is given by

$$e_{ss} = \frac{1}{K_v}$$

where

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

$$= \lim_{s\to 0} s\left[\frac{1}{s}G(s)\right] = 4$$

$$\therefore \quad e_{ss} = \frac{1}{4} = 0.25$$

47. (d)

Steady state error for unit parabolic input is given by

$$e_{ss} = \frac{1}{K_a}$$

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

$\because$ $$e_{ss} = 0.1 = \frac{1}{K_a}$$

$\Rightarrow$ $$K_a = 10$$

$\therefore$ $$\lim_{s \to 0} s^2 G(s) = \lim_{s \to 0} s^2 \left[\frac{K_P s + K_I}{s^2(s+1)}\right] = 10$$

$$K_I = 10$$

now to determine the value of K_P, we can use the stability condition using R - H criteria characteristic equation

$$1 + G_C(s)\, G_P(s) = 0$$

$$1 + \frac{(K_P s + K_I)}{s^2(s+1)} = 0$$

$$s^3 + s^2 + K_P s + K_I = 0$$

using Routh's tabular form

s^3	1	K_P
s^2	1	K_I
s^1	$K_P - K_I$	0
s^0	K_I	

for system to be stable

$$K_P - K_I > 0$$

$$K_P > K_I$$

hence, only in option (d) the condition is satisfied.

49. (d)

For unity feedback system

$$G(s)H(s) = \frac{K_i e^{-2s}}{s}$$

$$G(j\omega)H(j\omega) = \frac{K_i e^{-2j\omega}}{j\omega}$$

$$\angle G(j\omega)H(j\omega) = -2\omega - \frac{\pi}{2}$$

Hence, the phase angle equals to –180° at $\omega = \frac{\pi}{4}$ rad/sec

For stability, the magnitude $|G(j\omega)H(j\omega)|$

at $\omega = \frac{\pi}{4}$ must be less than unity.

$$|G(j\omega)H(j\omega)|_{\omega=\pi/4} = \left.\frac{K_i}{\omega}\right|_{\omega=\pi/4} < 1$$

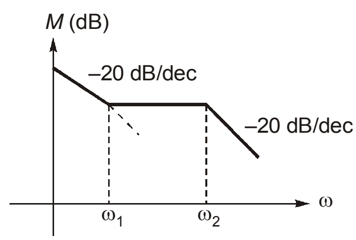
$$K_i < \frac{\pi}{4}$$

We require that $K_i < \frac{\pi}{4}$ for stability.

51. (a)

The transfer function of the given Bode plot can be derived as

$$G(s) = \frac{K(s+\omega_1)}{s(s+\omega_2)}$$



As the open loop transfer function represents a type 1 system thus

$$K_p = \infty$$

and $$e_{ss} = 0$$

52. (c)

$$\phi(\omega) = -\frac{\pi}{2} - \omega\tau$$

at $\omega = \omega_{pc} \Rightarrow$ $$-\frac{\pi}{2} - \omega_{pc}\tau = -\pi$$

$\because$ $$-5\tau = -\frac{\pi}{2}$$

or $$\tau = \frac{\pi}{10}$$

54. (c)

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)} = \frac{100}{s^2 + 100(s+1)}$$

$$\frac{C(s)}{R(s)} = \frac{100}{s^2 + 100s + 100}$$

$$C(s) = \frac{1}{s}\cdot\frac{100}{s^2+100s+100}$$ $\because R(s) = \frac{1}{s}$ for unit step input

$$c(\infty) = \lim_{s\to 0} s\cdot C(s) = \lim_{s\to 0}\frac{s}{s}\cdot\frac{100}{s^2+100s+100} = 1$$

55. (a)

For lead compensator

$$G_c(s) = \frac{a(1+s\tau)}{(1+as\tau)}$$

here $\tau = \frac{1}{\alpha}$

$$a\tau = \frac{1}{\beta}$$

or $a = \frac{\alpha}{\beta}$

$\because$ $a < 1$

or $\frac{\alpha}{\beta} < 1$

or $\alpha < \beta$

56. (b)

$$\text{Rise time} = t_r = \frac{\pi - \theta}{\omega_d}$$

where $\theta = \cos^{-1}\xi$

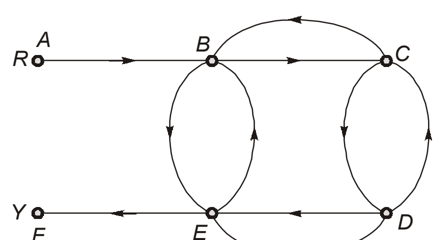
and $\omega_d = \omega_n\sqrt{1-\xi^2}$

$\therefore$ $t_r = \frac{\pi - \cos^{-1}\xi}{\omega_n\sqrt{1-\xi^2}}$

57. (c)

Synchro is a single phase machine.

58. (d)



Forward paths

1. *ABEF* 2. *ABCDEF*

Individual Loop

1. *BEB* 2. *CDC*
3. *BCB* 4. *EDE*
5. *BCDEB* 6. *BEDCB*

59. (b)

Resonant frequency

$$\omega_r = \omega_n\sqrt{1-2\xi^2}$$

$$= \sqrt{2}\sqrt{1-2(0.5)^2} = \sqrt{2}\times\frac{1}{\sqrt{2}} = 1\text{ rad/sec}$$

60. (d)

Here,

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

$$B = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

and

$$C = [1 \quad 1]$$

check for controllability

$$Q_C = [B \quad AB]$$

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

$$Q_C = \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

$\because$ $|Q_C| = 0$ $\therefore$ Not controllable

check for observability

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

$\Rightarrow$

$$C^T = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

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

$$Q_o = \begin{bmatrix} 1 & -1 \\ 1 & -1 \end{bmatrix}$$

$\because$ $|Q_o| = 0$ $\therefore$ Not observable

61. (d)

$$\frac{C(s)}{R(s)} = \frac{25}{s^2+10s+25}$$

or

$$G(s) = \frac{25}{s(s+10)}$$

by adding PD controller

$$G'(s) = G(s)\,G_d(s) = \frac{25}{s(s+10)}\times 10(1+0.1s)$$

$$G'(s) = \frac{25}{s} \Rightarrow T(s) = \frac{25}{s+25}$$

$\because$ System becomes first order system, hence damping ratio does not exists.

62. (c)

$\because \quad S_G^{T.F.} = \dfrac{1}{1+GH}$

and $\quad S_H^{T.F.} = \dfrac{-GH}{1+GH} \simeq -1$

$\Rightarrow$ Less sensitive to 'change in G' than 'change in H'.

64. (b)

Phase-lead compensation is used to decrease rise time and to decrease obvershoot.

65. (b)

$$\text{Delay element} = e^{-sT}$$
$$\text{Magnitude of delay element} = 1$$
$$\text{Phase} = -\tan^{-1}(\omega T)$$

Only phase of the transfer function is affected. Magnitude plot remains same.

66. (c)

The closed loop transfer function

$$T(s) = \frac{C(s)}{R(s)} = \frac{25}{s(s+6)+25}$$
$$= \frac{25}{s^2+6s+25}$$

By comparing with standard transfer function

$$\omega_n = 5 \text{ rad/sec}$$
$$2\xi\omega_n = 6$$
$$\xi\omega_n = \frac{6}{2} = 3$$
$$\xi = \frac{3}{5}$$
$$\text{peak time } \tau_p = \frac{\pi}{\omega_d} \approx \frac{22/7}{\omega_n\sqrt{1-\xi^2}}$$
$$= \frac{22/7}{5\sqrt{1-\left(\frac{3}{5}\right)^2}}$$
$$= \frac{22/7}{\frac{5}{5}\sqrt{25-9}}$$
$$= \frac{22/7}{4} = \frac{11}{14} \text{ sec}$$

67. (c)

The angular contribution of the lead compensator zero is more than that of the pole. Therefore bandwidth is increased.

75. (a)

$$\text{Gain with feedback} = \frac{A_v}{1+\beta \cdot A_v}$$

$$\beta A_v \gg 1$$

so,
$$\frac{A_v}{\beta A_v} = \frac{1}{\beta}$$

❍❍❍❍