CHAPTER

6.5

FREQUENCY-DOMAIN ANALYSIS

Statement for Q.1–2:

An under damped second order system having a transfer function of the form

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

has a frequency response plot shown in fig. P6.5.1–2.

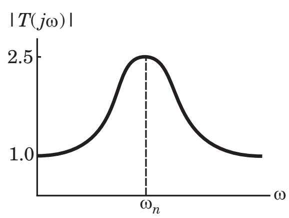


Fig. P6.5.1-2

1. The system gain K is

(A) 1 (B) 2

(C) $\sqrt{2}$ (D) $\frac{1}{\sqrt{2}}$

2. The damping factor ξ is approximately

(A) 0.6 (B) 0.2

(C) 1.8 (D) 2.4

3. For the transfer function

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

the phase cross-over frequency is

(A) 0.5 rad/sec (B) 0.707 rad/sec

(C) 1.732 rad/sec (D) 2 rad/sec

4. The gain-phase plots of open-loop transfer function of four different system are shown in fig. P6.5.4. The correct sequence of the increasing order of stability of these four system will be

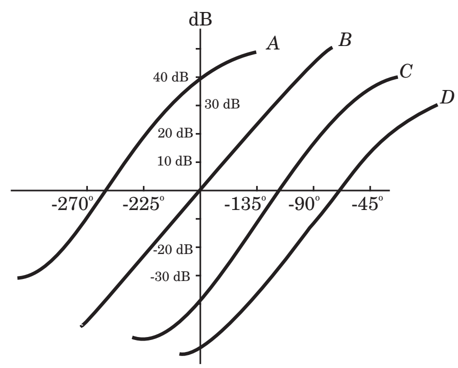


Fig. P6.5.4

(A) D, C, B, A (B) A, B, C, D

(C) B, C, A, D (D) A, D, B, C

5. The open-loop frequency response of a unity feedback system is shown in following table

ω	$\lvert G(j\omega)\rvert$	$\angle G(j\omega)$
2	8.5	–119°
3	6.4	–128°
4	4.8	–142°
5	2.56	–156°
6	1.4	–164°
8	1.00	–172°
10	0.63	–180°

Fig. P6.5.5

The gain margin and phase margin of the system are

(A) 2 dB, 8° (B) 2 dB, –172°

(C) 4 dB, 8° (D) 4 dB, –172°

Statement for Q.6–7:

Consider the gain-phase plot shown in fig. P6.5.6–7.

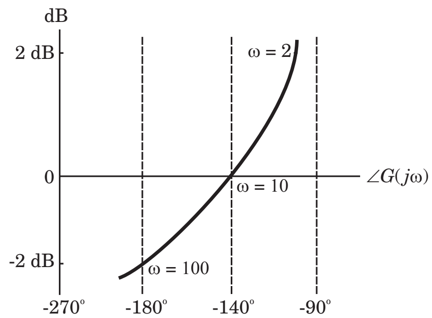


Fig. P6.5.6-7

6. The gain margin and phase margin are

(A) –2 dB, 40° (B) 2 dB, 40°

(C) 2 dB, 140° (D) –2 dB, 140°

7. The gain crossover and phase crossover frequency are respectively

(A) 10 rad/sec, 100 rad/sec

(B) 100 rad/sec, 10 rad/sec

(C) 10 rad/sec, 2 rad/sec

(D) 100 rad/sec, 2 rad/sec

8. The phase margin of a system with the open loop transfer function

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

(A) 68.3° (B) 90°

(C) 0 (D) ∞

9. Consider a *ufb* system having an open-loop transfer function

$$G(s) = \frac{K}{s(0.2s+1)(0.05s+1)}$$

For $K = 1$, the gain margin is 28 dB. When gain margin is 20 dB, K will be equal to

(A) 2 (B) 4

(C) 5 (D) 2.5

10. The gain margin of the *ufb* system

$$G(s) = \frac{2}{(s+1)(s+2)} \text{ is}$$

(A) 1.76 dB (B) 3.5 dB

(C) –3.5 dB (D) –1.76 dB

11. The open-loop transfer function of a system is

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

The phase crossover frequency is

(A) 6 rad/sec (B) 2.46 rad/sec

(C) 0.41 rad/sec (D) 3.23 rad/sec

12. The open-loop transfer function of a *ufb* system is

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

The corner frequencies are

(A) 0 and 2 (B) 0 and 1

(C) 0 and –1 (D) 1 and 2

13. In the Bode-plot of a unity feedback control system, the value of magnitude of $G(j\omega)$ at the phase crossover frequency is $\frac{1}{2}$. The gain margin is

(A) 2 (B) $\frac{1}{2}$

(C) $\frac{1}{3}$ (D) 3

14. In the Bode-plot of a *ufb* control system, the value of phase of $G(j\omega)$ at the gain crossover frequency is –120°. The phase margin of the system is

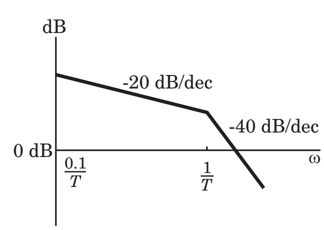
(A) –120° (B) 60°

(C) –60° (D) 120°

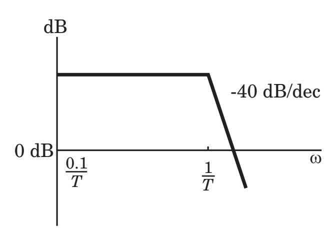
15. The transfer function of a system is given by

$$G(s) = \frac{K}{s(sT+1)} \;;\; K < \frac{1}{T}$$

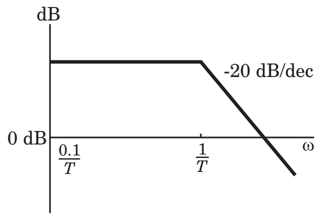
The Bode plot of this function is



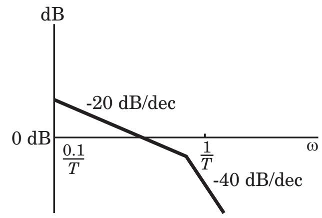
(A)



(B)



(C)



(D)

16. The asymptotic approximation of the log-magnitude versus frequency plot of a certain system is shown in fig. P6.5.16. Its transfer function is

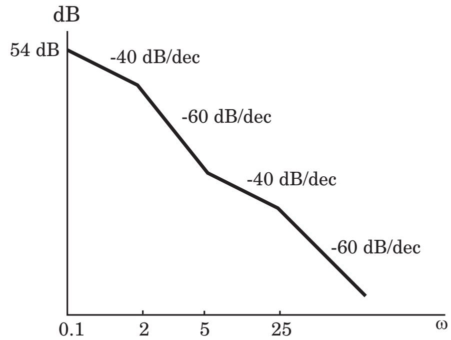


Fig. P6.5.16

(A) $\dfrac{50(s+5)}{s^2(s+2)(s+25)}$ (B) $\dfrac{20(s+5)}{s^2(s+2)(s+25)}$

(C) $\dfrac{10s^2(s+5)}{(s+2)(s+25)}$ (D) $\dfrac{20(s+5)}{s(s+2)(s+25)}$

17. For the Bode plot shown in fig. P6.5.17 the transfer function is

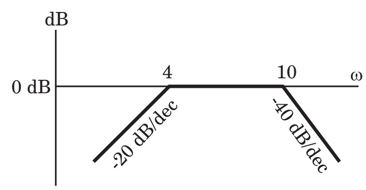


Fig. P6.5.17

(A) $\dfrac{100s}{(s+4)(s+10)^2}$ (B) $\dfrac{100(s+4)}{s(s+10)^2}$

(C) $\dfrac{100}{(s+4)(s+10)}$ (D) $\dfrac{100}{s^2(s+4)(s+10)}$

18. Bode plot of a stable system is shown in the fig. P6.3.18. The open-loop transfer function of the *ufb* system is

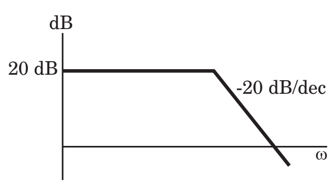


Fig. P6.5.18

(A) $\dfrac{100}{s+10}$ (B) $\dfrac{10}{s+10}$

(C) $\dfrac{1}{s+10}$ (D) None of the above

19. Consider the asymptotic Bode plot of a minimum phase linear system given in fig. P6.5.19. The transfer function is

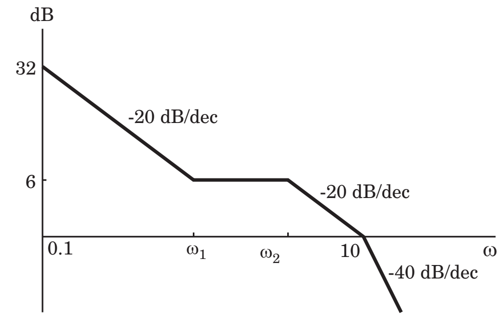


Fig. P6.5.19

(A) $\dfrac{8s(s+2)}{(s+5)(s+10)}$ (B) $\dfrac{4(s+5)}{(s+2)(s+10)}$

(C) $\dfrac{4(s+2)}{s(s+5)(s+10)}$ (D) $\dfrac{8s(s+5)}{(s+2)(s+10)}$

20. The Bode plot shown in fig. P6.5.20 represent

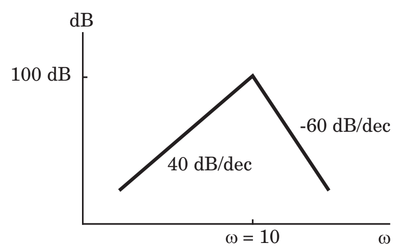


Fig. P6.5.20

(A) $\dfrac{100s^2}{(1+0.1s)^3}$ (B) $\dfrac{1000s^2}{(1+0.1s)^3}$

(C) $\dfrac{100s^2}{(1+0.1s)^5}$ (D) $\dfrac{1000s^2}{(1+0.1s)^5}$

Statement for Q.21–22:

The Bode plot of the transfer function $K/(1+sT)$ is given in the fig. P6.5.21–22.

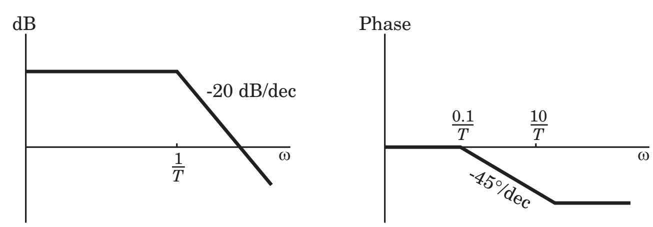


Fig. P6.5.21-22

Statement for Q.29–30:

Consider the Bode plot of a *ufb* system shown in fig. P6.5.29–30.

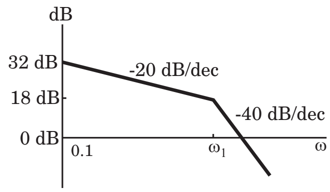


Fig. P6.5.29-30

29. The steady state error corresponding to a ramp input is

(A) 0.25 (B) 0.2

(C) 0 (D) ∞

30. The damping ratio is

(A) 0.063 (B) 0.179

(C) 0.483 (D) 0.639

31. The Nyquist plot of a open-loop transfer function $G(j\omega)H(j\omega)$ of a system encloses the $(-1, j0)$ point. The gain margin of the system is

(A) less than zero (B) greater than zero

(C) zero (D) infinity

32. Consider a *ufb* system

$$G(s) = \frac{K}{s(1+sT_1)(1+sT_2)(1+sT_3)}$$

The angle of asymptote, which the Nyquist plot approaches as $\omega \to 0$, is

(A) $-90°$ (B) $90°$

(C) $180°$ (D) $-45°$

33. If the gain margin of a certain feedback system is given as 20 dB, the Nyquist plot will cross the negative real axis at the point

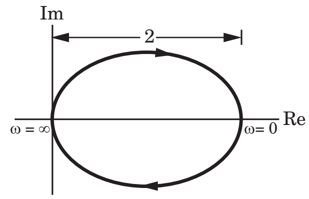
(A) $s = -0.05$ (B) $s = -0.2$

(C) $s = -0.1$ (D) $s = -0.01$

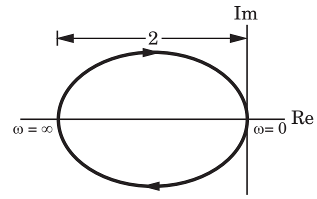
34. The transfer function of an open-loop system is

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

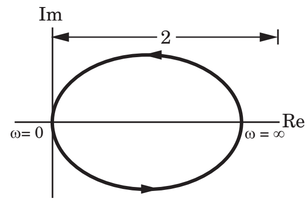
The Nyquist plot will be of the form



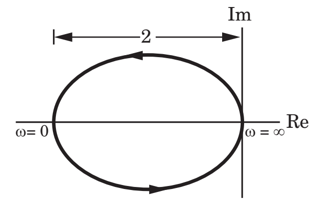
(A)



(B)



(C)

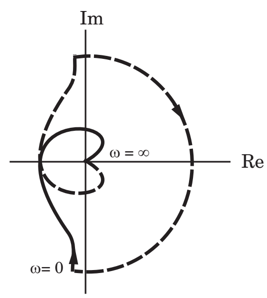


(D)

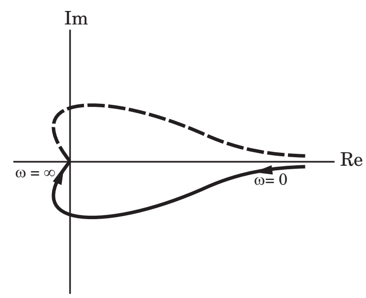
35. Consider a *ufb* system whose open-loop transfer function is

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

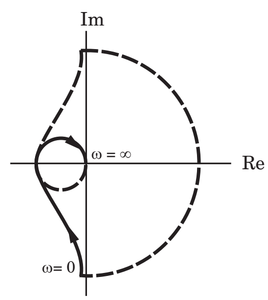
The Nyquist plot for this system is



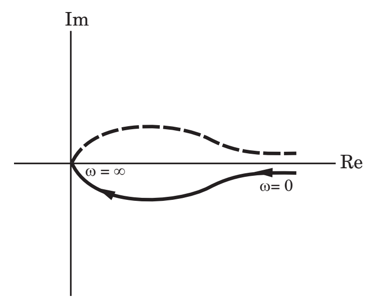
(A)



(B)



(C)

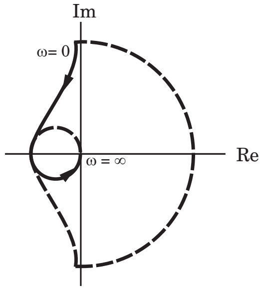


(D)

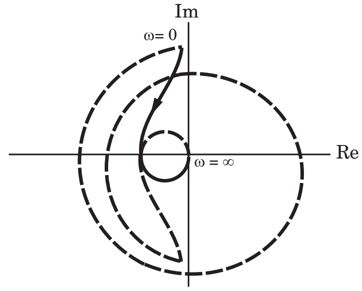
36. The open loop transfer function of a system is

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

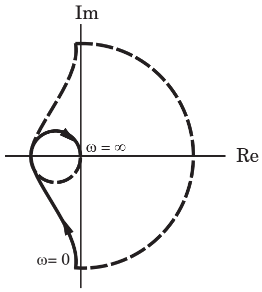
The Nyquist plot for this system is



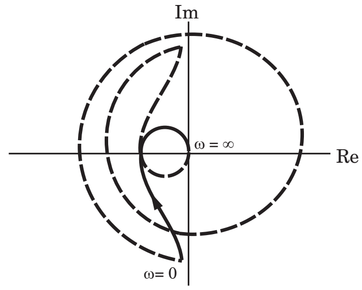
(A)



(B)



(C)

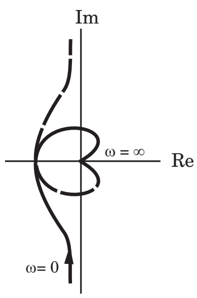


(D)

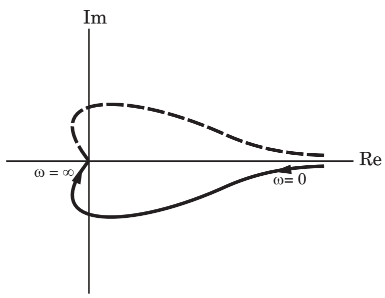
37. For the certain unity feedback system

$$G(s) = \frac{K}{s(s+1)(2s+1)(3s+1)}$$

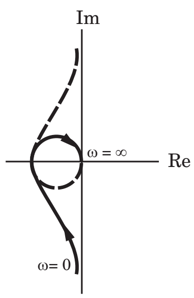
The Nyquist plot is



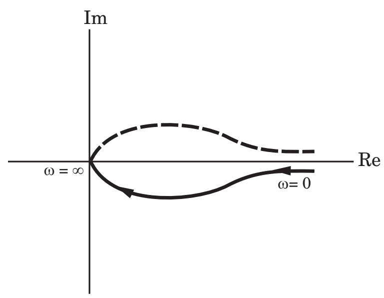
(A)



(B)



(C)



(D)

38. The Nyquist plot of a system is shown in fig. P6.5.38. The open-loop transfer function is

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

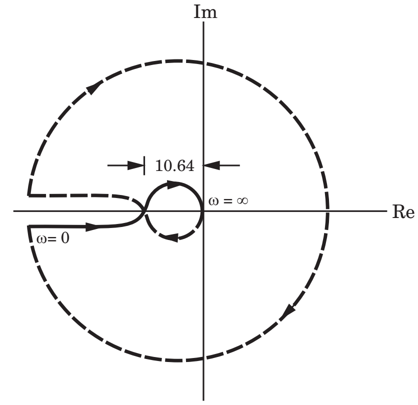


Fig. P6.5.38

The no. of poles of closed loop system in RHP are

(A) 0 (B) 1

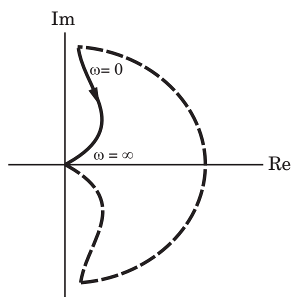
(C) 2 D) 4

Statement for Q.39–40:

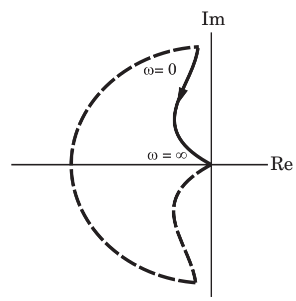
The open-loop transfer function of a feedback control system is

$$G(s)H(s) = \frac{-1}{2s(1-20s)}$$

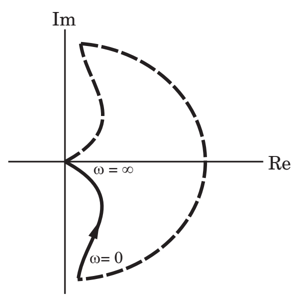
39. The Nyquist plot for this system is



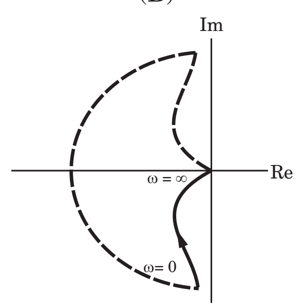
(A)



(B)



(C)



(D)

40. Regarding the system consider the statements

1. Open-loop system is stable
2. Closed-loop system is unstable
3. One closed-loop poles is lying on the RHP

The correct statements are

(A) 1 and 2 (B) 1 and 3

(C) only 2 (D) All

41. The Nyquist plot shown in the fig. P6.5.41 is for

(A) type–0 system (B) type–1 system

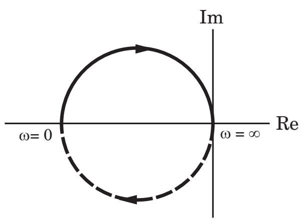
(C) type–2 system (D) type–3 system

Statement for Q.42–43:

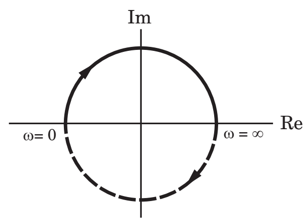
The open-loop transfer function of a feedback system is

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

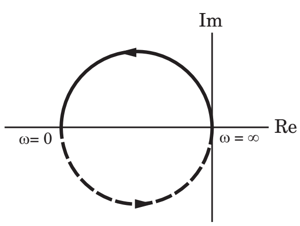
42. The Nyquist plot of this system is



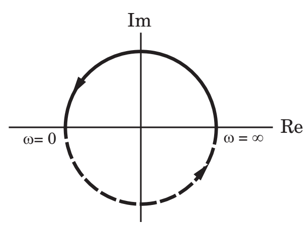
(A)



(B)



(C)



(D)

43. The system is stable for K

(A) $K > 1$ (B) $K < 1$

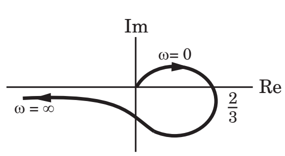
(C) any value of K (D) unstable

Statement for Q.44–46:

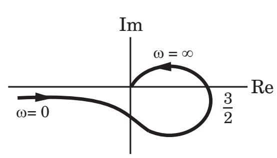
A unity feedback system has open-loop transfer function

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

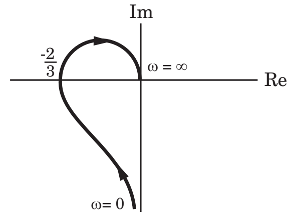
44. The Nyquist plot for the system is



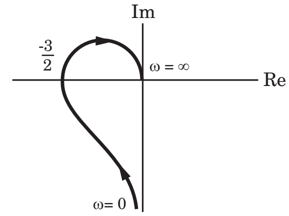
(A)



(B)



(C)



(D)

45. The phase crossover and gain crossover frequencies are

(A) 1.414 rad/sec, 0.57 rad/sec

(B) 1.414 rad/sec, 1.38 rad/sec

(C) 0.707 rad/sec, 0.57 rad/sec

(D) 0.707 rad/sec, 1.38 rad/sec

46. The gain margin and phase margin are

(A) –3.52 dB, –168.5° (B) –3.52 dB, 11.6°

(C) 3.52 dB, –168.5° (D) 3.52 dB, 11.6°

****

SOLUTIONS

1. (A) $T(s) = \dfrac{K\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$

$$T(j\omega) = \frac{K\omega_n^2}{-\omega^2 + 2j\xi\omega_n\omega + \omega_n^2}$$

$$|T(j\omega)|^2 = \frac{K^2\omega_n^4}{(\omega_n^2 - \omega^2)^2 + 4\xi^2\omega_n^2\omega^2}$$

From the fig. P6.5.1–2, $|T(j0)| = 1$

$$|T(j0)|^2 = \frac{K^2\omega_n^4}{\omega_n^4} = K^2 = 1 \quad \Rightarrow \quad K = 1$$

2. (B) The peak value of $T(j\omega)$ occurs when the denominator of function $|T(j\omega)|^2$ is minimum i.e. when

$$\omega_n^2 - \omega^2 = 0 \quad \Rightarrow \quad \omega = \omega_n$$

$$|T(j\omega_n)|^2 = \frac{K^2\omega_n^4}{4\xi^2\omega_n^4} = \frac{K^2}{4\xi^2} \quad \Rightarrow \quad |T(j\omega_n)| = \frac{K}{2\xi} = 2.5$$

$$\xi = \frac{K}{5} = 0.2$$

3. (B) $G(j\omega)H(j\omega) = \dfrac{1}{j\omega(j\omega + 1)(0.5 + j\omega)}$

$\phi = -90° - \tan^{-1} 2\omega - \tan^{-1}\omega$

At phase cross over point $\phi = -180°$

$-\tan^{-1} 2\omega - \tan^{-1}\omega - 90° = -180°$

$\tan^{-1} 2\omega + \tan^{-1}\omega = 90°$

$$\frac{2\omega + \omega}{1 - (2\omega)(\omega)} = \tan 90° = \infty$$

$$1 - (2\omega)\omega = 0 \Rightarrow \quad \omega = \frac{1}{\sqrt{2}} = 0.707 \text{ rad/sec}$$

4. (B) For a stable system gain at 180° phase must be negative in dB. More magnitude more stability.

5. (C) At 180° gain is 0.63. Hence gain margin is

$$= 20 \log \frac{1}{0.63} = 4 \text{ dB}$$

At unity gain phase is –172°,

Phase margin = 180°–172° = 8°

6. (A) At $\angle G(j\omega) = 180°$ gain is –2 dB. Hence gain margin is 2 dB. At 0 dB gain phase is –140°. Hence phase margin is 180°–140° = 40°.

7. (A) At $\omega = 100$ rad/sec phase is 180°. Phase cross-over frequency $\omega_\pi = 100$ rad/sec.

At $\omega = 10$ rad/sec gain is 0 dB. Gain cross over frequency $\omega = 10$ rad/sec.

8. (D) $|GH(j\omega)| \neq 1$, for any value of ω. Thus phase margin is ∞.

9. (D) For 28 dB gain Nyquist plot intersect the real axis at a,

$$20 \log \frac{1}{a} = 28 \quad \Rightarrow \quad a = 0.04$$

For 20 dB gain Nyquist plot should intersect at b,

$$20 \log \frac{1}{b} = 20 \quad \Rightarrow \quad b = 0.1.$$

This is achieved if the system gain is increased by factor $\dfrac{0.1}{0.04} = 2.5$. Thus $K = 2.5$.

10. (B) Here $K = 2, \quad T_1 = 1, \quad T_2 = \dfrac{1}{2}$

$$\text{Gain Margin} = \left[\frac{KT_1T_2}{T_1 + T_2}\right]^{-1} = \left[\frac{(2)(0.5)}{1 + 0.5}\right]^{-1} = 1.5 = 3.5 \text{ dB}$$

11. (C) For phase crossover frequency

$\angle GH(j\omega) = -180°$

$$GH(j\omega) = \frac{K}{j\omega(1 + 2j\omega)(1 + 3j\omega)}$$

$-90° - \tan^{-1} 2\omega_\pi - \tan^{-1} 3\omega_\pi = -180°$

$\tan^{-1} 2\omega_\pi + \tan^{-1} 3\omega_\pi = 90°$

$$\frac{2\omega_\pi + 3\omega_\pi}{1 - (2\omega_\pi)(3\omega_\pi)} = \tan 90°$$

$$1 - 6\omega_\pi^2 = 0 \quad \Rightarrow \quad \omega_\pi = 0.41 \text{ rad/s}$$

12. (D) $G(s) = \dfrac{s + 1}{s(1 + 0.5s)} = \dfrac{s + 1}{s\left(\dfrac{s}{2} + 1\right)}$

The Bode plot of this function has break at $\omega = 1$ and $\omega = 2$. These are the corner frequencies.

13. (A) G.M. $= \dfrac{1}{|GH(j\omega_\pi)|} = \dfrac{1}{½} = 2$

14. (B) P.M. $= 180° + \angle GH(j\omega_1) = 180° - 120° = 60°$

15. (D) Due to pole at origin initial plot has a slope of –20 dB/decade. At $s = j\omega = \dfrac{1}{T}$. Slope increases to –40 dB/decade. At $\omega = \dfrac{1}{T}$,

$|G(j\omega)| \approx KT < 1$,Gain in dB < 0.

27. (C) Initially slope is –20 dB/decade. Hence there is a pole at origin and system type is 1. For type–1 system position error coefficient is ∞.

$20\log K = 6 \quad \Rightarrow \quad K = 2,$

28. (B) The system is type –0,

$20 \log K_p = 40, \quad K_p = 100, \; e_{step}(\infty) = \dfrac{1}{1+K_p} = \dfrac{1}{101}$.

29. (A) The Bode plot is as shown in fig. S6.5.29

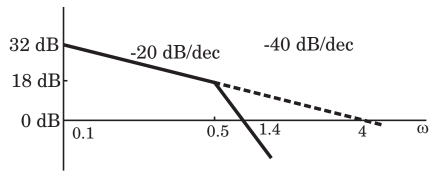


Fig.S6.5.29

$K_v = 4, \; e_{ramp}(\infty) = \dfrac{1}{K_v} = \dfrac{1}{4} = 0.25$

30. (B) From fig. S6.5.29 $\xi = \dfrac{\omega_2}{2\omega_3} = \dfrac{0.5}{2(1.4)} = 0.179$

31. (A) If Nyquist plot encloses the point $(-1, j0)$, the system is unstable and gain margin is negative.

32.(A) $GH(j\omega) = \dfrac{K}{j\omega(1+j\omega T_1)(1+j\omega T_2)(1+j\omega T_2)}$

$\lim_{\omega\to 0} GH(j\omega) = \lim_{\omega\to 0} \dfrac{K}{j\omega} = \lim_{\omega\to 0} \dfrac{K}{\omega} \angle -90°$

Hence, the asymptote of the Nyquist plot tends to an angle of $-90°$ as $\omega \to 0$.

33. (C) $20\log \dfrac{1}{|GH(j\omega)|} = 20$

$\dfrac{1}{|GH(j\omega)|} = 10 \quad \Rightarrow \quad |GH(j\omega)| = 0.1$

Since system is stable, it will cross at $s = -0.1$.

34. (B) $GH(s) = \dfrac{s+2}{(s^2-1)}$

$GH(j\omega) = \dfrac{j\omega + 2}{(-1-\omega^2)}$

At $\omega = 0$, $\quad GH(j\omega) = 2\angle -180°$

At $\omega = \infty$, $\quad GH(j\omega) = 0\angle -270°$

Hence (B) is correct option.

35. (C) $GH(j\omega) = \dfrac{K}{j\omega(-\omega^2 + 2j\omega + 2)}$

$\angle GH(j\omega) = -\tan^{-1}\dfrac{2\omega}{2-\omega^2} - 90°$

$|GH(j\omega)| = \dfrac{K}{\omega\sqrt{(2-\omega^2)^2 + 4\omega^2}}$

At $\omega = 0$, $\quad GH(j\omega) = \infty \angle -90°$,

At $\omega = \infty$ $\quad GH(j\omega) = 0\angle -270°$,

At $\omega = 1$, $\quad GH(j\omega) = \dfrac{K}{\sqrt{5}} \angle -153.43°$,

At $\omega = 2$, $\quad GH(j\omega) = \dfrac{K}{2\sqrt{18}} \angle -206.6°$,

Due to s there will be a infinite semicircle. Hence (C) is correct option.

36. (B) $GH(j\omega) = \dfrac{K(1+j\omega)^2}{(j\omega)^3}$

$|GH(j\omega)| = \dfrac{K(1+\omega^2)}{\omega^3}$

$\angle GH(j\omega) = -270° + 2\tan^{-1}\omega$

For $\omega = 0$, $GH(j\omega) = \infty\angle -270°$

For $\omega = 1$, $\angle GH(j\omega) = -180°$

For $\omega = \infty$, $GH(j\omega) = 0\angle -90°$

As ω increases from 0 to ∞, phase goes $-270°$ to $-90°$. Due to s^3 term there will be 3 infinite semicircle.

37. (A) $|GH(j\omega)| = \dfrac{K}{\sqrt{1+\omega^2}\sqrt{1+4\omega^2}\sqrt{1+9\omega^2}}$,

$\angle GH(j\omega) = -90° - \tan^{-1}\omega - \tan^{-1}2\omega - \tan^{-1}3\omega$,

For $\omega = 0$, $GH(j\omega) = \infty\angle -90°$,

For $\omega = \infty$, $GH(j\omega) = 0\angle -360°$,

Hence (A) is correct option.

38. (C) The open-loop poles in RHP are $P = 0$. Nyquist path enclosed 2 times the point $(-1 + j0)$. Taking clockwise encirclements as negative $N = -2$.

$N = P - Z$, $\quad -2 = 0 - Z$, $\quad Z = 2$ which implies that two poles of closed-loop system are on RHP.

39. (B) $G(s)H(s) = \dfrac{-1}{2s(1-20s)}$,

$|GH(j\omega)| = \dfrac{1}{2\omega\sqrt{1+400\omega^2}}$

$\angle GH(j\omega) = 180° - 90° - \tan^{-1}\dfrac{-20\omega}{1}$,

At $\omega = 0$ $GH(j\omega) = \infty\angle 90°$

At $\omega = \infty$ $GH(j\omega) = 0\angle 180°$

At $\omega = 0.1$ $GH(j\omega) = 2.24\angle 153.43°$

At $\omega = 0.01$ $GH(j\omega) = 49\angle 91.15°$

40. (C) One open-loop pole is lying on the RHP. Thus open-loop system is unstable and $P = 1$. There is one clockwise encirclement. Hence $N = -1$.

$Z = P - N = 1 - (-1) = 2,$

Hence there are 2 closed-loop poles on the RHP and system is unstable.

41. (B) There is one infinite semicircle. Which represent single pole at origin. So system type is1.

42. (D) $|GH(j\omega)| = \dfrac{K\sqrt{1+\omega^2}}{\sqrt{1+\omega^2}} = K$

$\angle GH(j\omega) = \tan^{-1}\omega - \tan^{-1} - \dfrac{-\omega}{1}$

At $\omega = 0$ $GH(j\omega) = K\angle 0°$,

At $\omega = 1$ $GH(j\omega) = K\angle 90°$,

At $\omega = 2$ $GH(j\omega) = K\angle 127°$,

At $\omega = \infty$ $GH(j\omega) = K\angle 180°$,

43. (A) RHP poles of open-loop system $P = 1$, $Z = P - N$.

For closed loop system to be stable,

$Z = 0,\ \ 0 = 1 - N \ \Rightarrow\ \ N = 1$

There must be one anticlockwise rotation of point $(-1 + j0)$. It is possible when $K > 1$.

44. (C) $G(s) = \dfrac{1}{s(2s+1)(s+1)}$, $\quad H(s) = 1$

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

$$GH(j\omega) = \frac{1}{j\omega(2j\omega+1)(j\omega+1)}$$

$$\lim_{\omega\to 0} GH(j\omega) = \lim_{\omega\to 0}\frac{1}{j\omega} = \infty\angle -90°$$

$$\lim_{\omega\to\infty} GH(j\omega) = \lim_{\omega\to\infty}\omega\frac{1}{2(j\omega)^3} = 0\angle -270°$$

The intersection with the real axis can be calculated as $\text{Im}\{GH(j\omega)\} = 0$, The condition gives $\omega(2\omega^2 - 1) = 0$

i.e. $\omega = 0,\ \dfrac{1}{\sqrt{2}},\quad GH\left(j\dfrac{1}{\sqrt{2}}\right) = \dfrac{-2}{3}$

With the above information the plot in option (C) is correct.

45. (C) The Nyquist plot crosses the negative real axis at $\omega = \dfrac{1}{\sqrt{2}}$ rad/sec. Hence phase crossover frequency is

$\omega_\pi = \dfrac{1}{\sqrt{2}} = 0.707$ rad/sec.

The frequency at which magnitude unity is

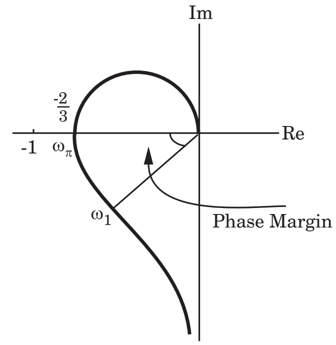


Fig.S6.5.44

$\omega_1^2(1+\omega_1^2)(1+4\omega_1^2) = 1$

$\omega^2 = 0.326,\quad \omega_1 = 0.57$ rad/sec

46. (D) G.M. $= 20\log\dfrac{1}{|GH(j\omega_\pi)|}$, $\qquad |GH(j\omega_\pi)| = \dfrac{2}{3}$

Gain Margin $= 20\log\dfrac{3}{2} = 3.52$ dB.

$\angle GH(j\omega) = -90° - \tan^{-1}\omega - \tan^{-1}2\omega$,

At unit gain $\omega_1 = 0.57$ rad/sec,

Phase at this frequency is

$\angle GH(j\omega_1) = -90° - \tan^{-1}0.57 - \tan^{-1}2(0.57) = -168.42°$

Phase margin $= -168.42° + 180° = 11.6°$

Note that system is stable. So gain margin and phase margin are positive value. Hence only possible option is (D).

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