Polar Plot Questions

MCQ Question 1

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A system with a unity gain margin and zero phase margin is ______

1. Sluggish
2. highly stable
3. oscillatory
4. relatively stable

Answer (Detailed Solution Below)

Option 3 : oscillatory

Polar Plot MCQ Question 1 Detailed Solution

Explanation:

1. Gain margin (GM): The gain margin of the system defines by how much the system gain can be increased so that the system moves on the edge of stability.

2. It is determined from the gain at the phase cross-over frequency.

$$GM = \frac{1}{|G(j\omega)H(j\omega)|_{\omega=\omega_{pc}}}$$

3. Phase crossover frequency (ω_{pc}): It is the frequency at which the phase angle of G(s) H(s) is -180°.

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

4. Phase margin (PM): The phase margin of the system defines by how much the phase of the system can increase to make the system unstable.

$$PM = 180^{\circ} + \angle G(j\omega) H(j\omega)|_{\omega=\omega_{gc}}$$

5. It is determined from the phase at the gain cross over frequency.

6. Gain crossover frequency (ω_{gc}): It is the frequency at which the magnitude of G(s) H(s) is unity.

$$|G(j\omega) H(j\omega)|_{\omega=\omega_{gc}} = 1$$

7. So it is important to note that these margins of stability are valid for open-loop stable systems only.

8. A large gain margin or a large phase margin indicates a very stable feedback system but usually a very sluggish response.

9. Hence a Gain margin close to unity (or 0 in dB) or a phase margin close to zero corresponds to a highly oscillatory system.

Hence **option (3) is the correct answer.**

Gain margin and phase margin are frequently used for frequency response specifications by designers. Usually a **Gain margin of about 6 dB or a Phase margin of 30 - 35°** results in a reasonably good degree of relative stability.

Important Points

- If both GM and PM are positive, the system is stable ($\omega_{gc} < \omega_{pc}$)
- If both GM and PM are negative, the system is unstable ($\omega_{gc} > \omega_{pc}$)
- If both GM and PM are zero, the system is just stable ($\omega_{gc} = \omega_{pc}$)

MCQ Question 2

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Polar plot of sinusoidal transfer function is a plot of:

1. magnitude and phase angle
2. magnitude versus frequency

3. phase angle versus frequency

4. none of the above

Answer (Detailed Solution Below)

Option 1 : magnitude and phase angle

Polar Plot MCQ Question 2 Detailed Solution

Polar plot:

- **The polar plot of a transfer function G(jω) is the plot of the magnitude of G(jω) versus the phase angle of G(jω) as ω is varied from 0 to positive infinity.**
- For all pole systems, type indicates the starting point of the polar plot and order indicates the ending point of the polar plot.

The sinusoidal transfer function G(jω) is a complex function and it is given by

G(jω) = Re [G(jω)] + j Im [G(jω)]

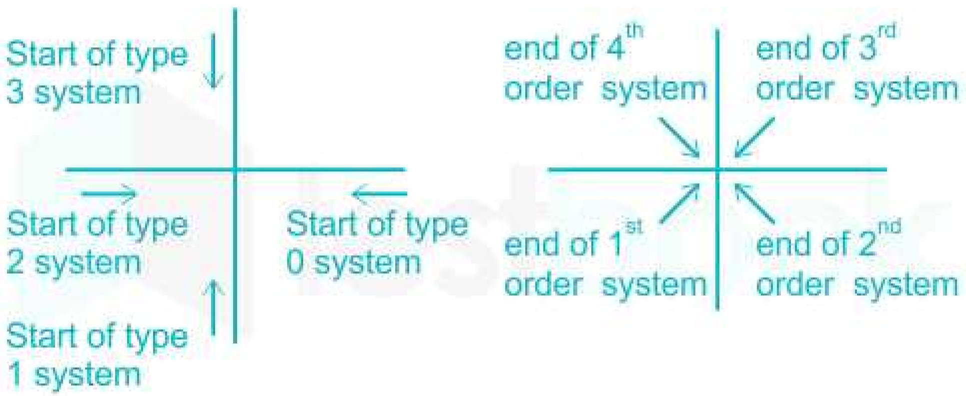
G(jω) = $|G(j\omega)|\angle G(j\omega)$

= M ∠ϕ Polar form

From the above equation,

G(jω) may be represented as a phasor of magnitude M and phase angle ϕ

The starting points (ω = 0) of a polar plot for different types of minimum phase systems is given below:



- As seen from the above figure, when a zero is added the type decreases, and the end of the polar plot shifts by +90°.
- When a pole is added, the type of the system increases, and hence the end of the polar plot shifts by -90°.

Therefore, the Polar plot of the sinusoidal transfer function is a plot of magnitude and phase angle.

MCQ Question 3

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If the constant 'k' is negative, then what would be its contribution to the phase plot:

1. 90 degrees
2. 45 degrees
3. 180 degrees
4. 0 degree

Answer (Detailed Solution Below)

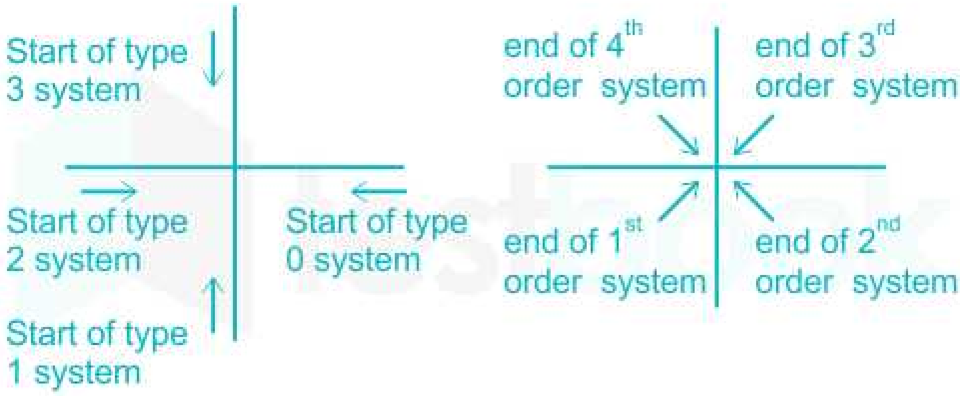
Option 3 : 180 degrees

Polar Plot MCQ Question 3 Detailed Solution

Concept:

Polar plot:

- The polar plot of a transfer function G(jω) is the plot of the magnitude of G(jω) versus the phase angle of G(jω) as ω is varied from 0 to positive infinity.
- For all pole systems, type indicates the starting point of the polar plot and order indicates the ending point of the polar plot.



- As seen from the above figure, when a zero is added the type decreases, and the end of the polar plot shifts by +90°.
- When a pole is added, the type of the system increases, and hence the end of the polar plot shifts by -90°.

Calculation:

Let the transfer function be:

$$G\left(s\right)=\frac{K}{s(1+sT)}$$

s =jω

$$G\left(j\omega\right)=\frac{K}{j\omega(1+j\omega T)}$$

$$\left|G\left(j\omega\right)\right|=\frac{K}{\omega\sqrt{1+\omega^2T^2}}$$

The total phase shift will be:

$\angle G(j\omega)H(j\omega) = -90° - \tan^{-1}(\omega T) - 180°$ ----(1)

From equation (1) we can say that constant K has no contribution to the phase plot.

Hence K contributes 180° to the phase plot.

So **option (3)** is the correct answer.

MCQ Question 4

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The polar plot of the transfer function $G(s) = \frac{10(s+1)}{(s+10)}$ for 0 ≤ ω ≤ ∞ will be in the

1. First quadrant
2. Second quadrant
3. Third quadrant
4. Fourth quadrant

Answer (Detailed Solution Below)

Option 1 : First quadrant

Polar Plot MCQ Question 4 Detailed Solution

Given transfer function

$G(j\omega) = \frac{10(j\omega+1)}{(j\omega+10)}$ (it is Lead compensator)

Magnitude of the transfer function will be

$M = \frac{10\sqrt{\omega^2+1}}{\sqrt{\omega^2+100}}$

Phase of the transfer function will be

$\phi = \tan^{-1}(\omega) - \tan^{-1}\left(\frac{\omega}{10}\right)$

At ω = 0

Magnitude M_1 = 1 and phase ϕ_1 = 0°

At ω = ∞

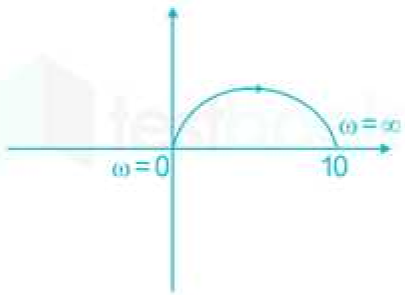
Magnitude M_2 = 10 and phase ϕ_2 = 0°

At ω = 2

Magnitude M_3 = 2.19 and phase ϕ_3 = 52.12°

The polar plot considering the above magnitude and phase values will be

Polar Plot



Zero is nearer to the imaginary axis than the pole, hence the plot will move in a clockwise direction.

MCQ Question 5

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System is said to be marginally stable, if

1. Gain crossover frequency > Phase crossover frequency
2. Gain crossover frequency = Phase crossover frequency
3. Gain crossover frequency < Phase crossover frequency
4. Gain crossover frequency ≠ Phase crossover frequency

Answer (Detailed Solution Below)

Option 2 : Gain crossover frequency = Phase crossover frequency

Polar Plot MCQ Question 5 Detailed Solution

Concept:

Gain Margin:

- The gain margin is a factor by which the gain of a stable system is allowed to increase before the system reaches the verge of instability.
- It is also defined as the reciprocal of the gain at which the phase angle becomes 180^0.
- **The frequency at which the phase angle is 180^0 is called the phase crossover frequency (ω_{pc}).**

Mathematically,

$\angle G(j\omega)H(j\omega) = -180^0$

If $|G(j\omega)H(j\omega)| = a$, at $\omega = \omega_{pc}$

Then Gain margin,

$$G.M. = 20log\frac{1}{a}db$$

Phase Margin:

- It is the amount of additional phase lag (at gain crossover frequency) that is required to bring the system to the verge of instability.
- **The frequency at which $|G(j\omega)H(j\omega|$, the magnitude of the open-loop transfer function is unity is called gain crossover frequency (ω_{pc}).**

At $\omega_{pc,}$ $|G(j\omega)H(j\omega| = 1$

if, $\angle G(j\omega)H(j\omega) = \phi$ at $\omega = \omega_{gc}$

Then, P.M. = $180 + \phi$

Analysis:

Condition	Gain margin	Phase margin	Closed-loop system stability
$\omega_{pc} > \omega_{gc}$	Positive	Positive	Stable
$\omega_{pc} = \omega_{gc}$	0 dB	0°	Marginal stable
$\omega_{pc} < \omega_{gc}$	Negative	Negative	Unstable

For stable systems,

$|G(j\omega_{pc})H(j\omega_{pc}| < 1$, and

$\angle G(j\omega_{gc})H(j\omega_{gc}) > -180$

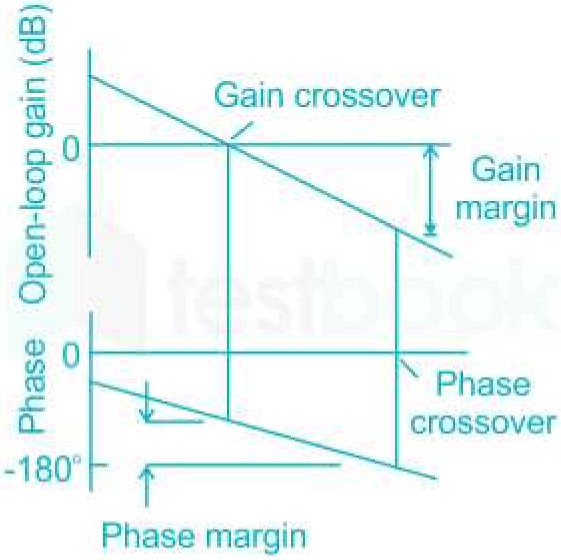
so that, gain margin and phase margin both are positive

which is possible when $\boldsymbol{\omega_{gc} < \omega_{pc}}$

For marginally stable systems,

$\omega_{gc} = \omega_{pc}$

Hence **option (2) is the correct answer.**



Note:

For stable systems having two or more gain crossover frequencies, the phase margin is measured at the highest gain crossover frequency.

MCQ Question 6

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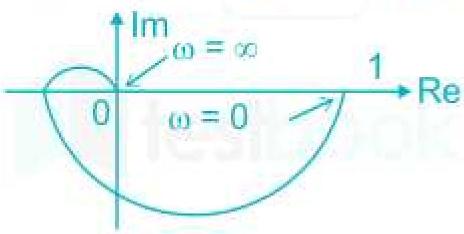
The transfer function of the following polar plot is



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

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

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

4. $G(s) = \frac{1}{s^2(1+sT_1)(1+sT_2)}$

Answer (Detailed Solution Below)

Option 3 : $G(s) = \frac{1}{(1+sT_1)(1+sT_2)(1+sT_3)}$

Polar Plot MCQ Question 6 Detailed Solution

From the given polar plot,

At ω = 0, magnitude = 1, angle = 0°

Therefore, there are **no poles or zeros at the origin**.

At ω = ∞, magnitude = 0, angle = -270°

Therefore, **the number of poles = 3**

From the above two conditions, the transfer function will be

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

MCQ Question 7

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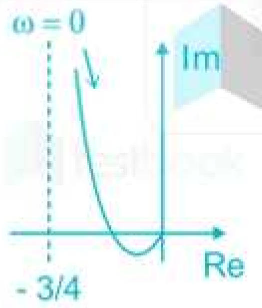
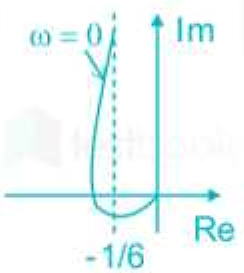
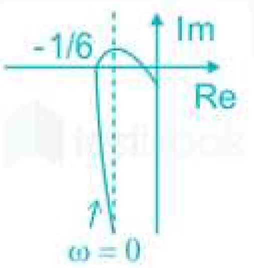
The frequency response of $G(s) = \frac{1}{s(s+1)(s+2)}$ plotted in the complex G(jω) plane (for 0 < ω < ∞) is

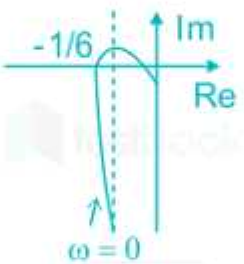
1. 

2. 

3. 

4. 

Answer (Detailed Solution Below)

Option 4 : 

Polar Plot MCQ Question 7 Detailed Solution

The given frequency response is

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

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

$$|G(j\omega)| = \frac{1}{\omega\left(\sqrt{\omega^2+1}\right)\left(\sqrt{\omega^2+4}\right)}$$

$$\angle G(j\omega) = -90 - \tan^{-1}\omega - \tan^{-1}0.5\omega$$

In Anti-clockwise the phase order is 0, 90, 180, 270, 360 or 0.

In clockwise the phase angle order is 0, -90, -180, -270, -360 or 0.

Here, $90^\circ = -270^\circ$ and $270^\circ = -90^\circ$

Frequency (ω) in rad/sec	$\lvert G(j\omega)\rvert$	$\angle G(j\omega)$
0	∞	-90°
∞	0	-270°

At $\omega = \omega_c$ (Cut-off frequency), $\angle G(j\omega) = -180^\circ$

$$-90 - \tan^{-1}\omega_c - \tan^{-1}0.5\omega_c = -180$$

$$\tan^{-1}\omega_c + \tan^{-1}0.5\omega_c = 90$$

$$\tan^{-1}\frac{\omega_c+0.5\omega_c}{1-0.5\omega^2} = 90^\circ$$

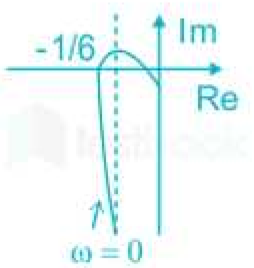
$1 - 0.5\omega_c^2 = 0$

$\omega_c = 1.414$ rad/sec

At $\omega = \omega_c$

$\lvert G(j\omega)\rvert = (1/6)$

The polar plot for given transfer function is



MCQ Question 8 View this Question Online >

The polar plot of a transfer function with ω as the parameter is known as the

1. Nyquist plot
2. bode plot
3. Root-locus
4. Signal flow graph

Answer (Detailed Solution Below)

Option 1 : Nyquist plot

Polar Plot MCQ Question 8 Detailed Solution

Nyquist plot:

Nyquist plots are an extension of polar plots for finding the stability of the closed-loop control systems. This is done by varying ω from −∞ to ∞, i.e. Nyquist plots are used to draw the complete frequency response of the open-loop transfer function.

Method of drawing Nyquist plot:

- Locate the poles and zeros of open-loop transfer function G(s)H(s) in 's' plane.
- Draw the polar plot by varying ω from zero to infinity.
- Draw the mirror image of the above polar plot for values of ω ranging from −∞ to zero.
- The number of infinite radii half circles will be equal to the number of poles at the origin.

- The infinite radius half-circle will start at the point where the mirror image of the polar plot ends. And this infinite radius half-circle will end at the point where the polar plot starts.

MCQ Question 9 View this Question Online >

Directions: It consists of two statements, one labelled as the 'Statement (I)' and the other as 'Statement (II)'. Examine these two statements carefully and select the answers to

as "Statement (II)". Examine these two statements carefully and select the answers to these items using the codes given below:

Statement (I):

The polar plot has limitation for portraying the frequency response of a system.

Statement (II):

The calculation of frequency response is tedious and does not indicate the effect of the individual poles and zeros.

1. Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
2. Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)
3. Statement (I) is true but Statement (II) is false
4. Statement (I) is false but Statement (II) is true

Answer (Detailed Solution Below)

Option 4 : Statement (I) is false but Statement (II) is true

Polar Plot MCQ Question 9 Detailed Solution

Polar plot:

- The Polar plot is a plot, which can be drawn between the magnitude and the phase angle of $G(j\omega)H(j\omega)$ by varying ω from zero to ∞.

MCQ Question 10:

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A system with a unity gain margin and zero phase margin is ______

1. Sluggish
2. highly stable
3. oscillatory
4. relatively stable

Answer (Detailed Solution Below)

Option 3 : oscillatory