1.1. $G_1(s) = \frac{10}{s+10} = \frac{1}{\left(1+\frac{s}{10}\right)}$

(1) Poles $= -10$ corner frequency $= 10$

$G_1(0) = \frac{10}{10} = 1$

1.1 $G(j\omega) = \frac{10}{j\omega + 10} = \frac{1}{1 + j\omega/10}$

Corner frequency = 10 rad/s.

$\omega >> 10$

$G(j\omega) = \frac{1}{j\frac{\omega}{10}} = \frac{10}{j\omega}$

Magnitude (in dB)

$= 20[\log(10) - \log(j\omega)]$

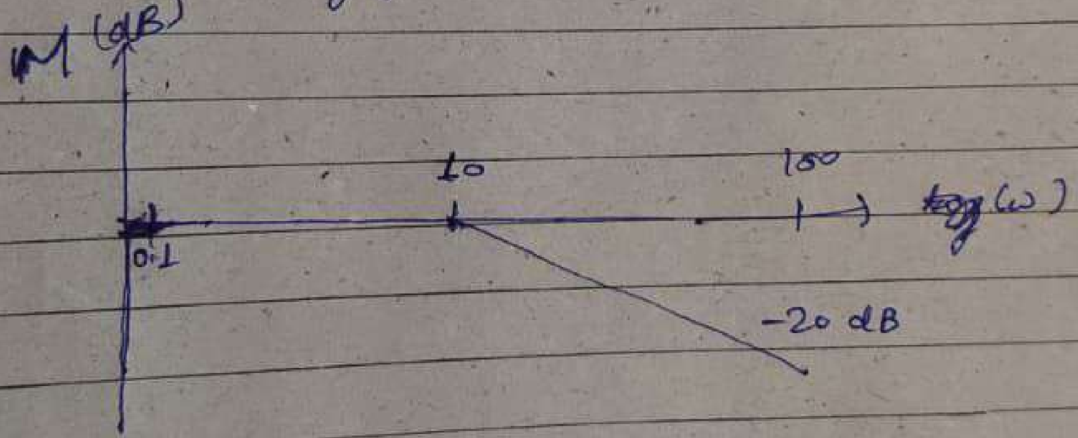
$= 20[1 - \log j\omega]$

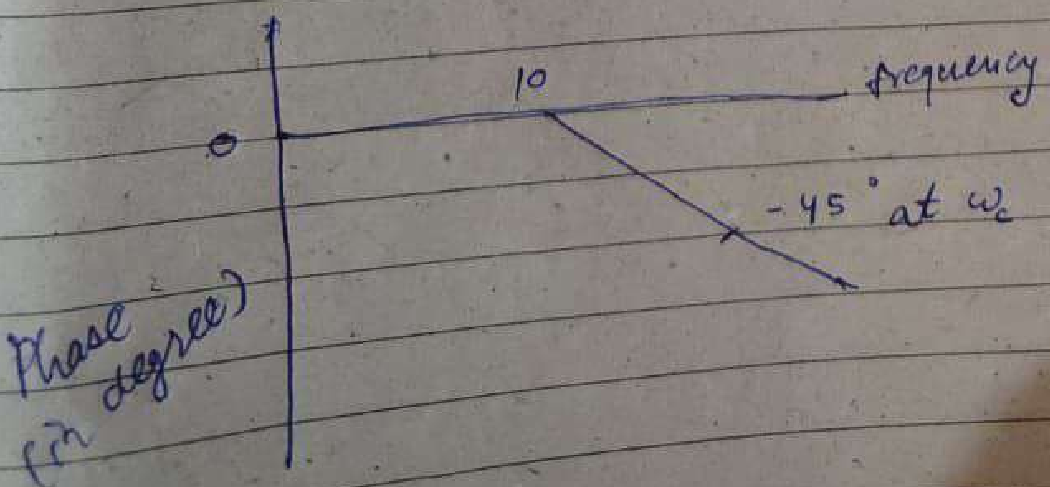
$\omega << 10$

$G(j\omega) = \frac{1}{1+0} = 1$

Magnitude (dB)

$= 20\log 1 = 0$

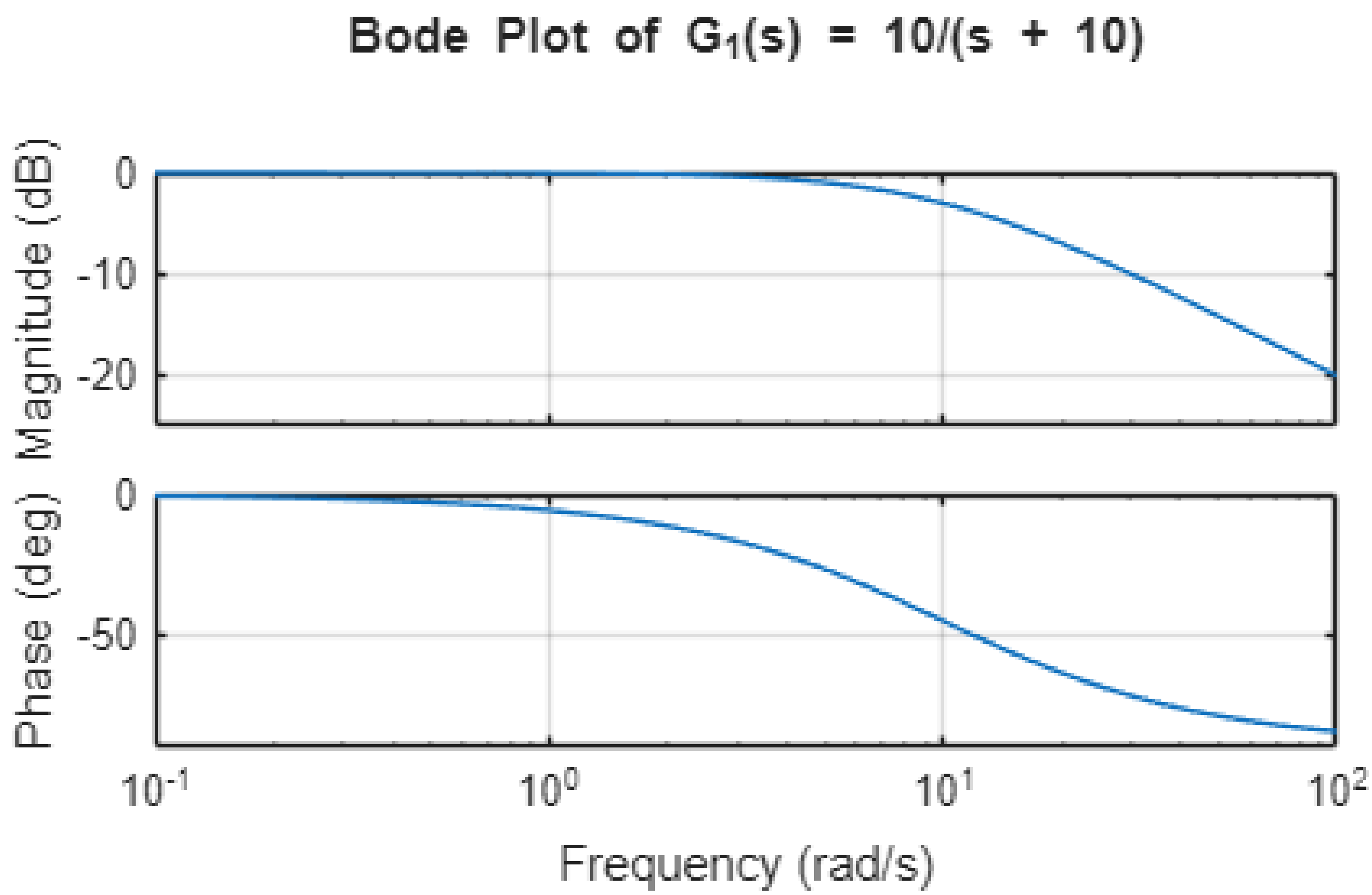




```matlab
s = tf('s');
G1 = 10/(s + 10);

w = logspace(-1, 2, 500);  % Frequency range: 0.1 to 100 rad/s

figure;
bode(G1, w);
grid on;
title('Bode Plot of G_1(s) = 10/(s + 10)');
```


Bode Plot of G1(s) = 10/(s + 10)
Magnitude (dB)
0
-10
-20
Phase (deg)
0
-50
10-1
100
101
102
Frequency (rad/s)

1-2 $G_2(s) = \frac{s-2}{s+10} = \frac{1}{5}\left(\frac{\frac{s}{2}-1}{\frac{s}{10}+1}\right)$

Zeroes $= 2$ poles $= -10$

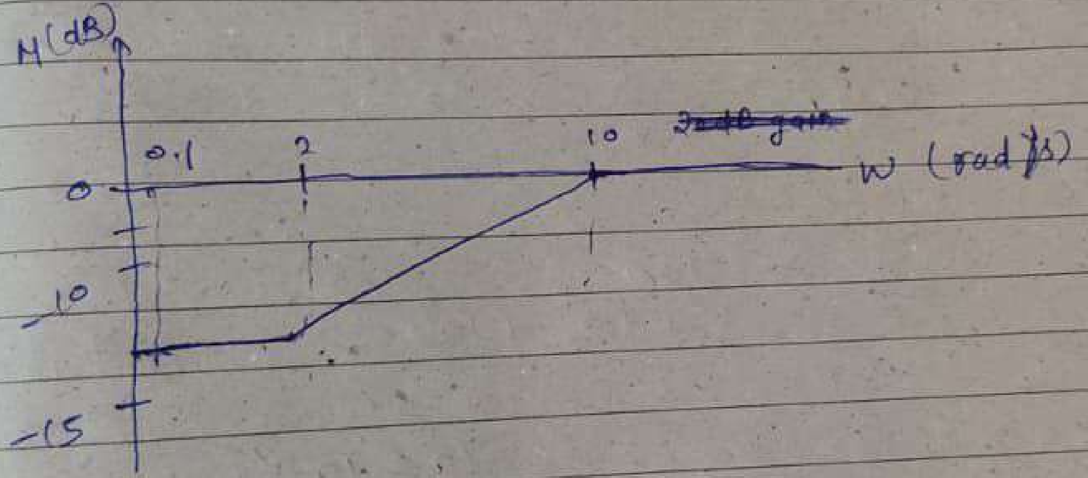
Cutoff freq $= 2, 10$

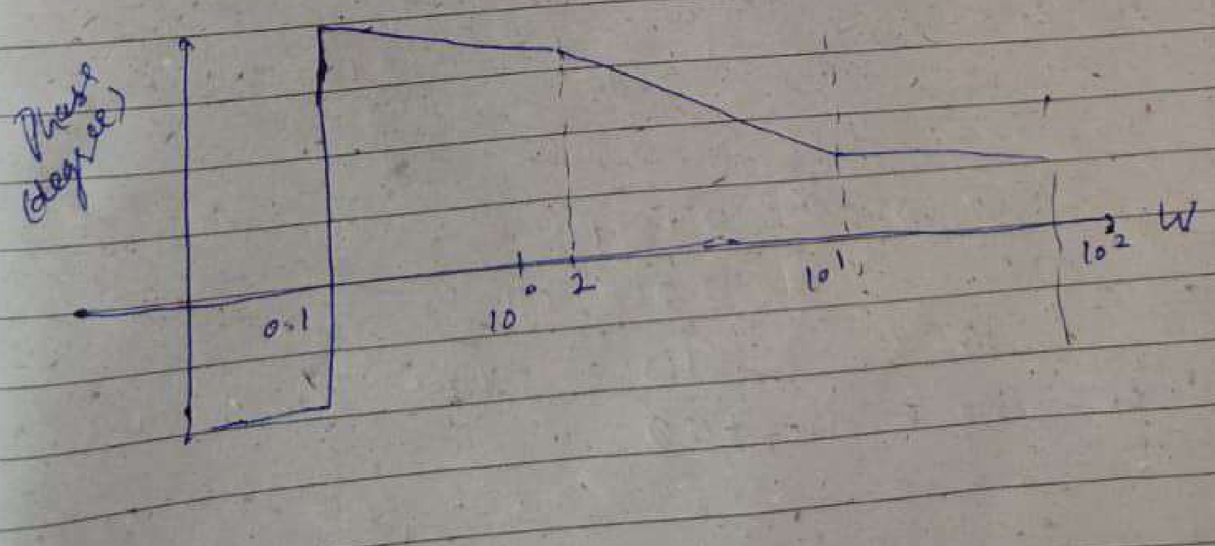
$G_2(0) = \frac{-2}{10} = -5$

1.2) $G_2(s) = \dfrac{s-2}{s+10} = \dfrac{1}{5}\left(\dfrac{\frac{s}{2}-1}{\frac{s}{10}+1}\right)$

$\omega_c = 2, 10$ [rad/s]

$\omega < 2$	$2 < \omega < 10$	$\omega > 10$
$G(s) = -1/5$	$G(s) = \frac{s}{2} \times \frac{1}{5} = \frac{s}{10}$	$G(s) = 1$
$M = 20[\log[1] - \log 5]$	$M = 20[\log s - 1]$	$M = 0$
$= -20 \log 5$	$M = -20 + 20 \log j\omega$	

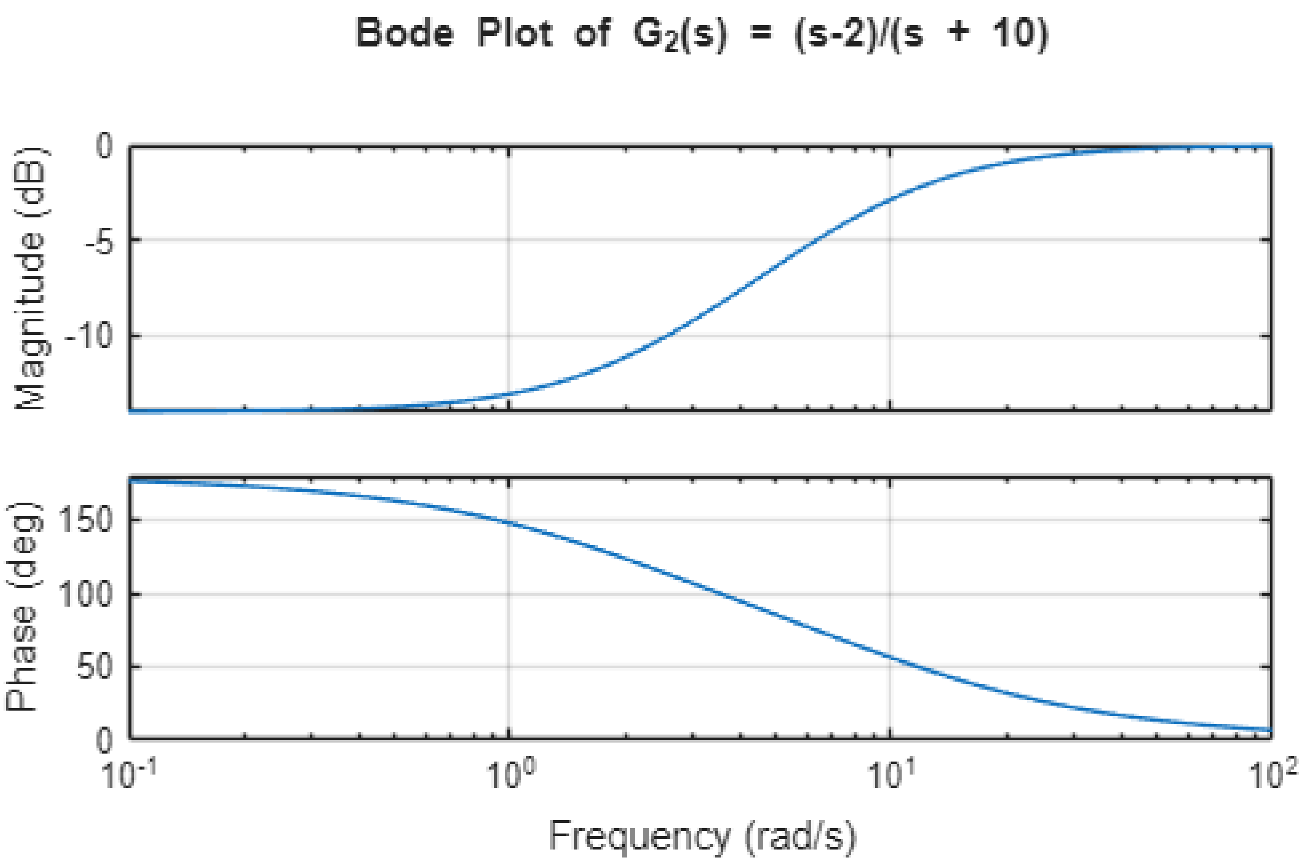




```
s = tf('s');
G2 = (s-2)/(s + 10);

w = logspace(-1, 2, 500);  % Frequency range: 0.1 to 100 rad/s

figure;
bode(G2, w);
grid on;
title('Bode Plot of G_2(s) = (s-2)/(s + 10)');
```



Bode Plot of G2(s) = (s-2)/(s + 10)
Magnitude (dB)
0
-5
-10
Phase (deg)
150
100
50
0
10-1
100
101
102
Frequency (rad/s)

2.d) A RHP (right half plane) zero contributes $-90°$ phase (instead of $+90°$. LHP zero), producing extra phase lag that worsens transient and feedback performance.

1.3 $G_3(s) = \dfrac{100}{s^2 + 10s + 100} = \dfrac{1}{\frac{s^2}{100} + \frac{s}{10} + 1}$

$$\text{Poles} = \frac{-10 \pm \sqrt{100 - 400}}{2} = \frac{-10 \pm 10\sqrt{3}i}{2} = -5 \pm 5\sqrt{3}i$$

$$\text{Poles} = -5 + 5\sqrt{3}i \;,\; -5 - 5\sqrt{3}i$$

(1.3) $G(j\omega) = \dfrac{100}{(j\omega)^2 + 10(j\omega) + 100} = \dfrac{1}{\left(\frac{j\omega}{10}\right)^2 + \frac{j\omega}{10} + 1}$

$\omega_c = 10$

$\omega > 10$

$G(j\omega) = \dfrac{1}{\left(\frac{j\omega}{10}\right)^2}$

$G(j\omega) = \dfrac{-100}{\omega^2}$

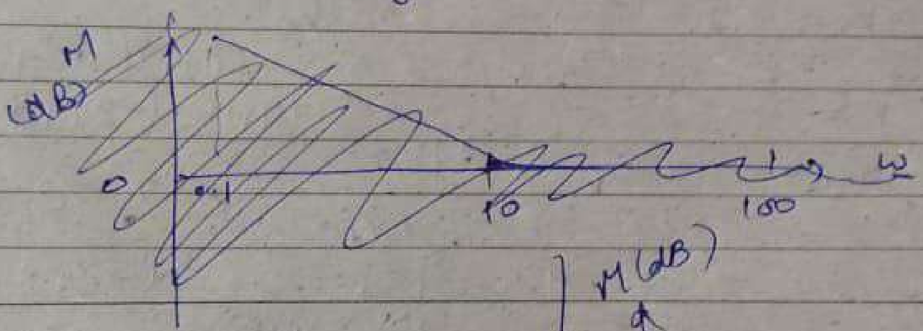
$M = 20\left[2 - 2\log\omega\right]$

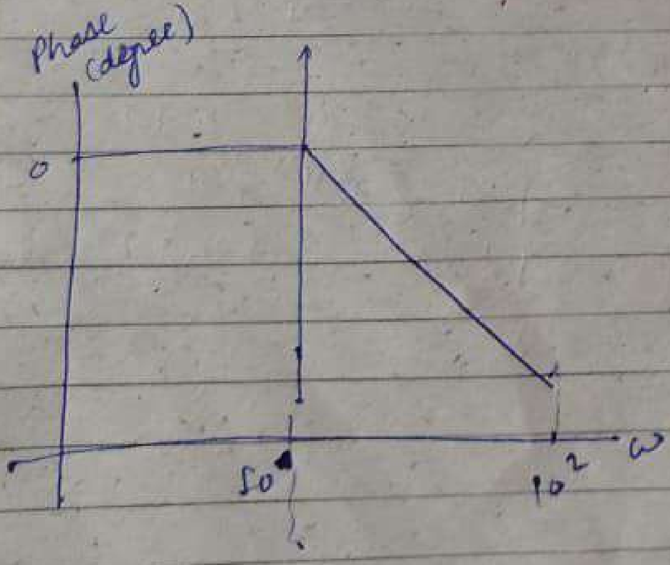
$M = 40 - 40\log\omega$

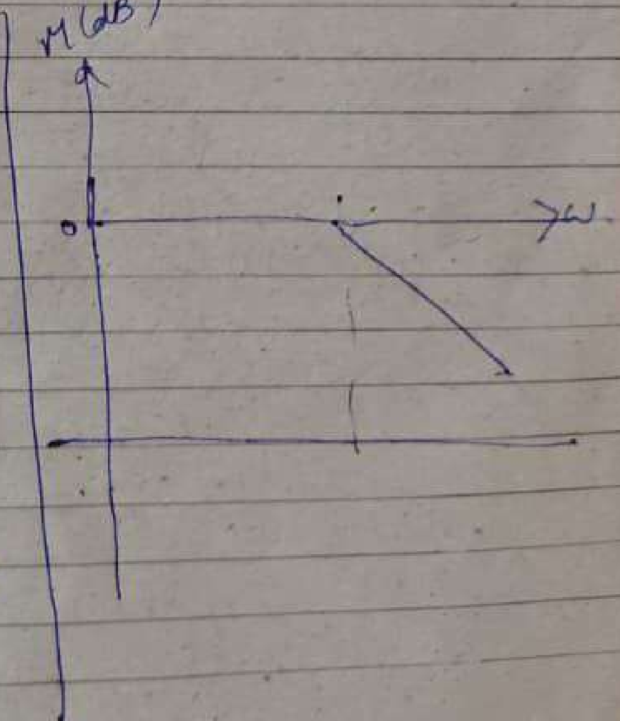
$\omega < 10$

$G(j\omega) = \dfrac{1}{1} = 1$

$M = 0$



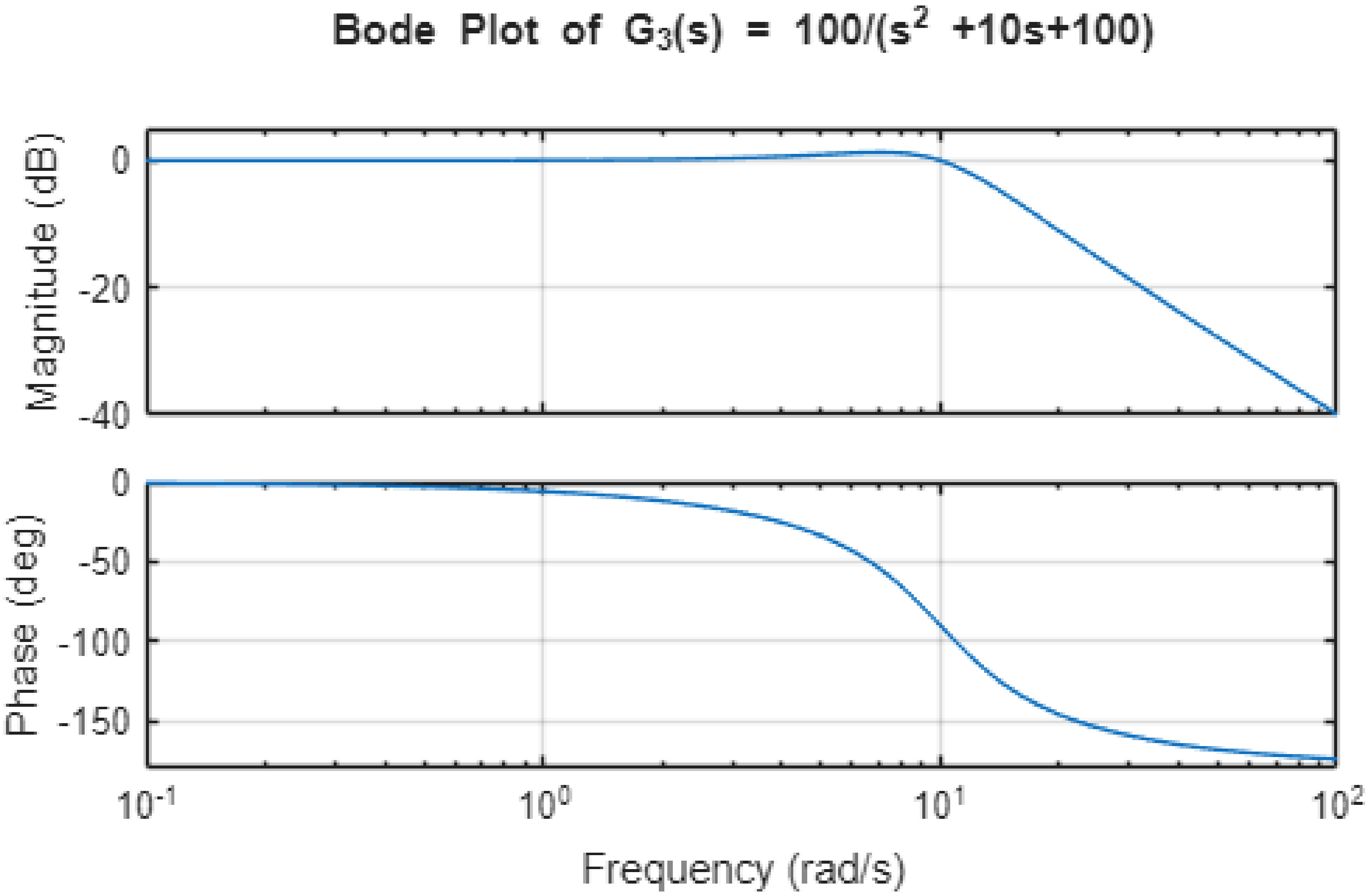




```
s = tf('s');
G3 = 100/(s^2 +10*s+100);

w = logspace(-1, 2, 500);  % Frequency range: 0.1 to 100 rad/s

figure;
bode(G3, w);
grid on;
title('Bode Plot of G_3(s) = 100/(s^2 +10s+100)');
```


Bode Plot of G3(s) = 100/(s2 +10s+100)
Magnitude (dB)
0
-20
-40
Phase (deg)
0
-50
-100
-150
10-1
100
101
102
Frequency (rad/s)

1.4 $G_4(s) = \dfrac{0.1s+1}{0.01s+1}$

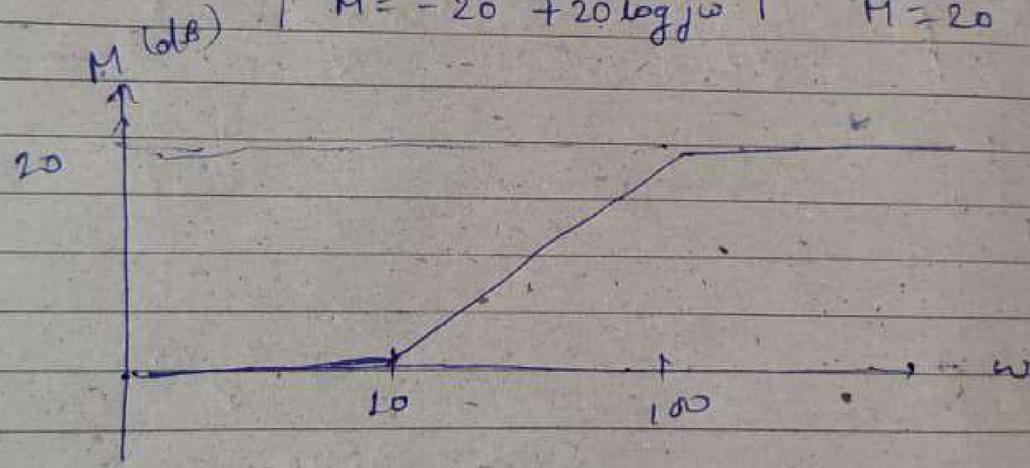
Zeroes $= -10$ Poles $= -100$

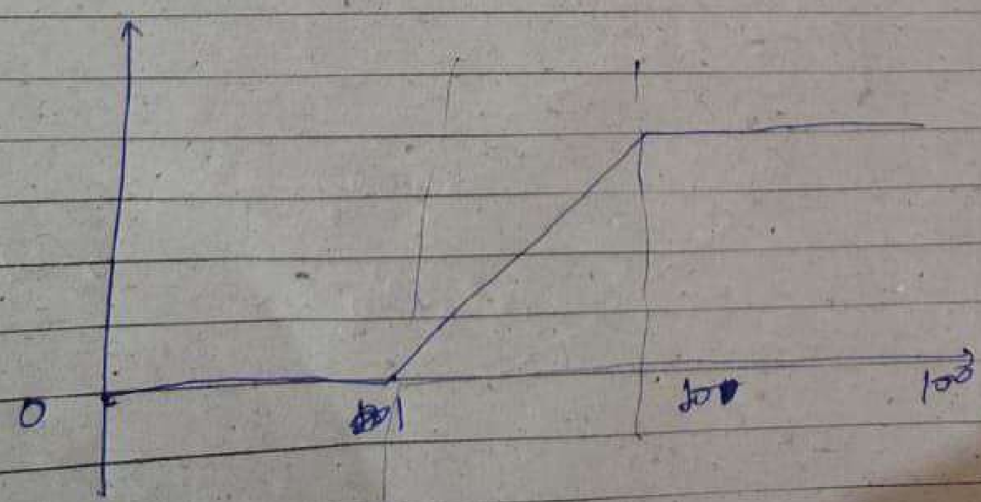
cutoff freq $= 10, 100$

(1.4) $G(j\omega) = \dfrac{\frac{j\omega}{10} + 1}{\frac{j\omega}{100} + 1}$

$\omega_c = 10, 100$

$\omega < 10$	$10 < \omega < 100$	$\omega > 100$
$G(j\omega) = 1$	$G(j\omega) = \frac{j\omega}{10}$	$G(j\omega) = 10$
$M = 0$	$M = 20[\log j\omega - 1]$	$M = 20\log 10$
	$M = -20 + 20\log j\omega$	$M = 20$



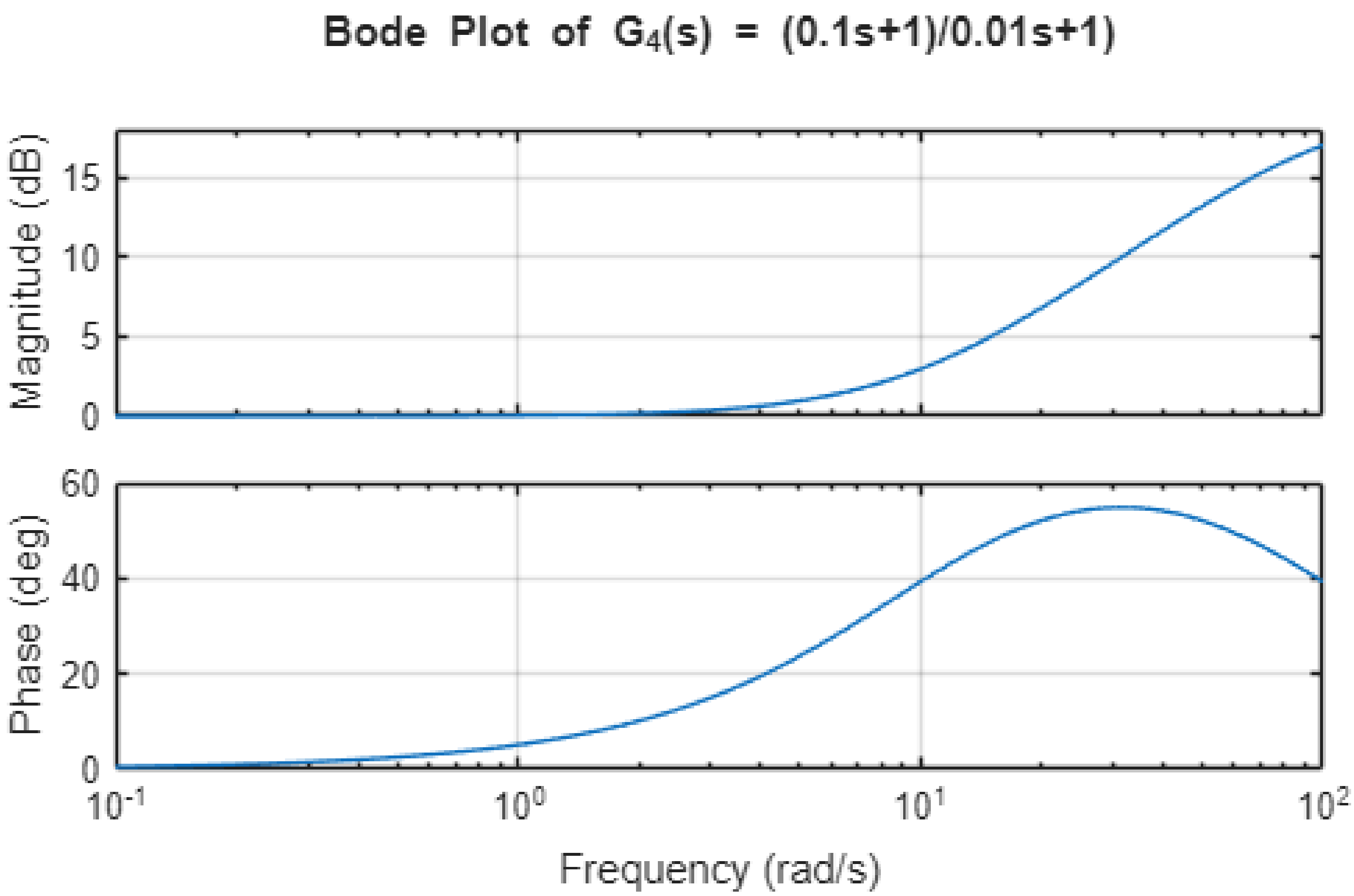


4.d) Between the zero ($\omega_z = 10$) and the pole ($\omega_p = 100$) the LHP zero is contributing $+90°$ lead while the pole is $-90°$ lag has not yet kicked in, so the net effect is positive phase.

```
s = tf('s');
G4 = (0.1*s+1)/(0.01*s+1);

w = logspace(-1, 2, 500);  % Frequency range: 0.1 to 100 rad/s

figure;
bode(G4, w);
grid on;
title('Bode Plot of G_4(s) = (0.1s+1)/0.01s+1)');
```



Bode Plot of G4(s) = (0.1s+1)/0.01s+1)
Magnitude (dB)
15
10
5
0
Phase (deg)
60
40
20
0
10-1
100
101
102
Frequency (rad/s)

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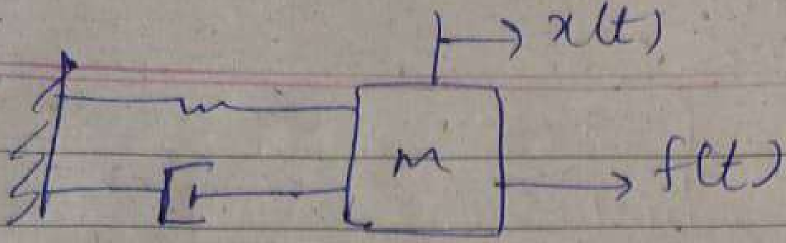
Q2 / B.1



a) $m\dfrac{d^2x(t)}{dt^2} = F(t) - c\dfrac{dx(t)}{dt} - kx$

$\Rightarrow \quad F(t) = m\dfrac{d^2x(t)}{dt^2} + c\dfrac{dx(t)}{dt} + kx$

b) Laplace transform (zero ICs)
Take Laplace (initial conditions = 0)

$ms^2X(s) + \cancel{s}\,csX(s) + kX(s) = F(s)$

c) Transfer function $\quad G(s) = \dfrac{X(s)}{F(s)}$

$G(s) = \dfrac{1}{ms^2 + cs + k}$

Q.2 $G(s) = \dfrac{1}{ms^2 + cs + k}$

$= \dfrac{1}{(1)s^2 + (4)s + 16}$

$G(s) = \dfrac{1}{s^2 + 4s + 16}$

Poles $= \dfrac{-4 \pm j\sqrt{48}}{2} = -2 \pm 2\sqrt{3}j$

DC gain $= G(0) = \dfrac{1}{16} = 0.0625$

$\omega_n = 4$ rad/sec

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B]

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

$\omega_c = 4$ rad/sec

$\omega < 4$

$G(j\omega) = 1$

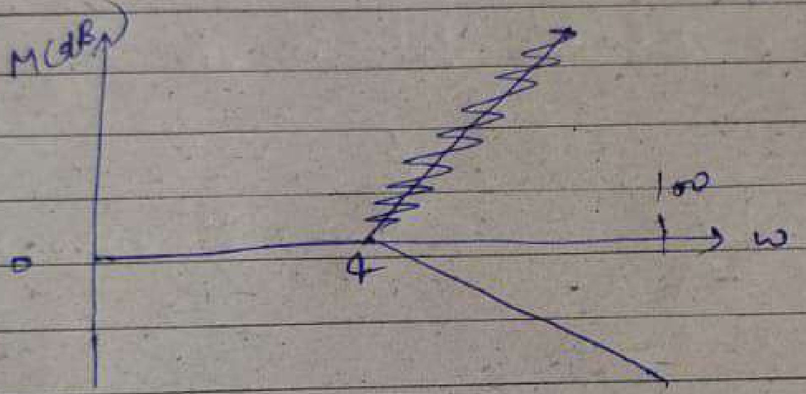
$M = 0$

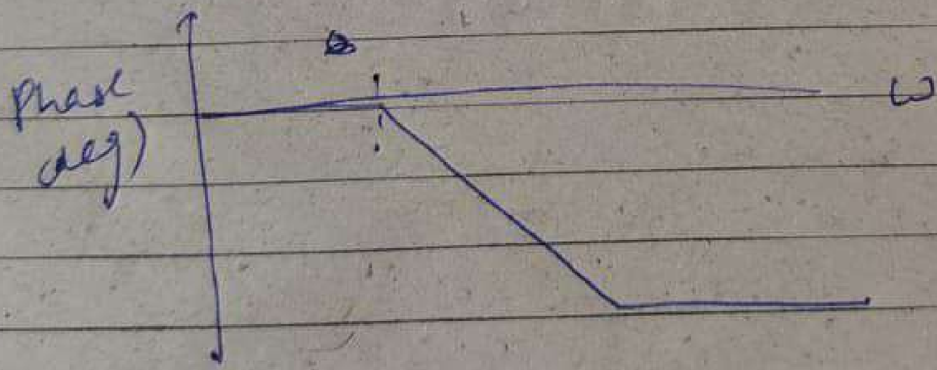
$\omega > 4$

$G(j\omega) = \frac{-16}{\omega^2}$

$M = 20\left[\log 16 - 2\log\omega\right]$

$M = 80\log 2 - 40\log\omega$

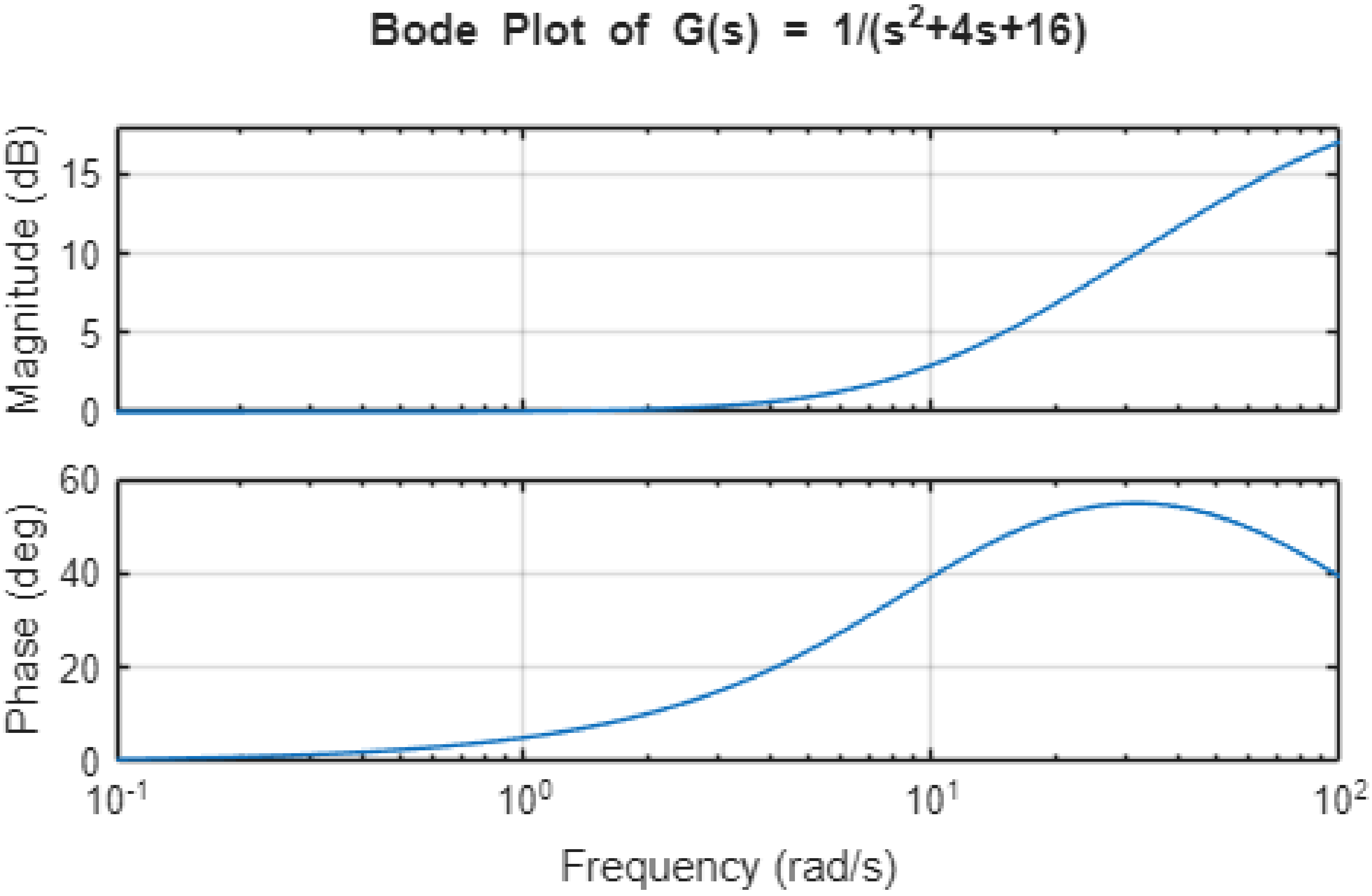




```
s = tf('s');
G =1/(s^2+4*s+16);

w = logspace(-1, 2, 500);  % Frequency range: 0.1 to 100 rad/s

figure;
bode(G4, w);
grid on;
title('Bode Plot of G(s) = 1/(s^2+4s+16)');
```


Bode Plot of G(s) = 1/(s2+4s+16)
Magnitude (dB)
15
10
5
0
Phase (deg)
60
40
20
0
10-1
100
101
102
Frequency (rad/s)