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Experiment 1

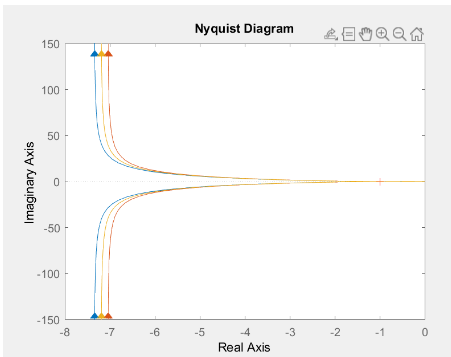
Aim: To show the Nyquist criteria of given transfer functions.

Theory: The Nyquist stability criterion works on the principle of argument. It states that if there are P poles and Z zeros are enclosed by the 's' plane closed path, then the corresponding G(s)H(s) plane must encircle the origin P−Z times. So, we can write the number of encirclements N as N = P – Z.
Nyquist stability criterion states the number of encirclements about the critical point (1+j0) must be equal to the poles of the characteristic equation, which is nothing but the poles of the open loop transfer function in the right half of the 's' plane. The shift in origin to (1+j0) gives the characteristic equation plane.

a) $L(s) = \frac{K}{s(s+2)(s+10)}$ for K < 240 & K > 240

Code and Output:

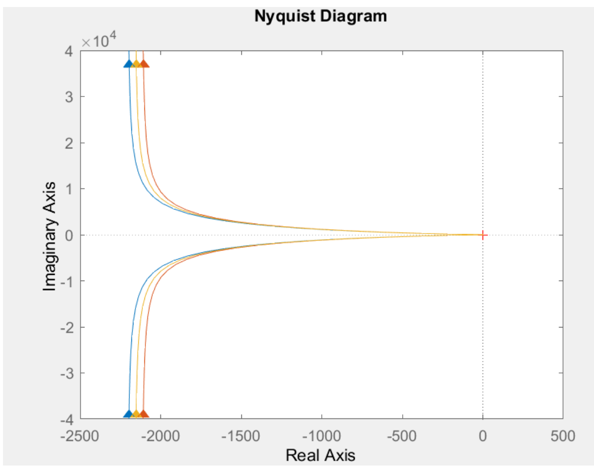
```
clear all;
close all;
clc;
num1=[245];
num2=[235];
num3=[240];
den=[1 12 20 0];
func1=tf(num1,den);
func2=tf(num2,den);
func3=tf(num3,den);
nyquist(func1,func2,func3);
```



b) $L(s) = \frac{K(s+2)}{s^3 + s^2 + 10}$

Code and Output:

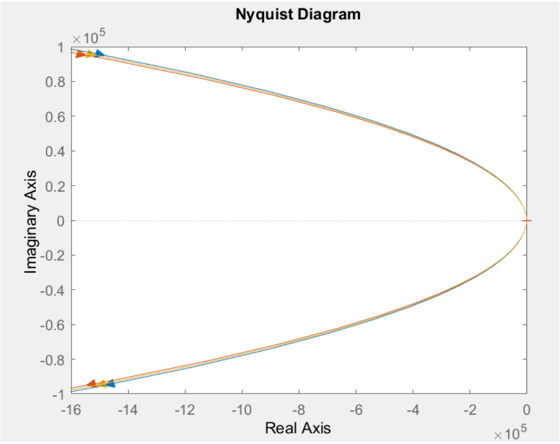
```
clear all;
close all;
clc;
k1=245;
k2=235;
k3=240;
num1=[k1 2*k1];
num2=[k2 2*k2];
num3=[k3 2*k3];
den=[5 1 0];
func1=tf(num1,den);
func2=tf(num2,den);
func3=tf(num3,den);
nyquist(func1,func2,func3)
```



$$\text{III. } L(s) = \frac{1}{s^2(1+T_1 s)}$$

Code:

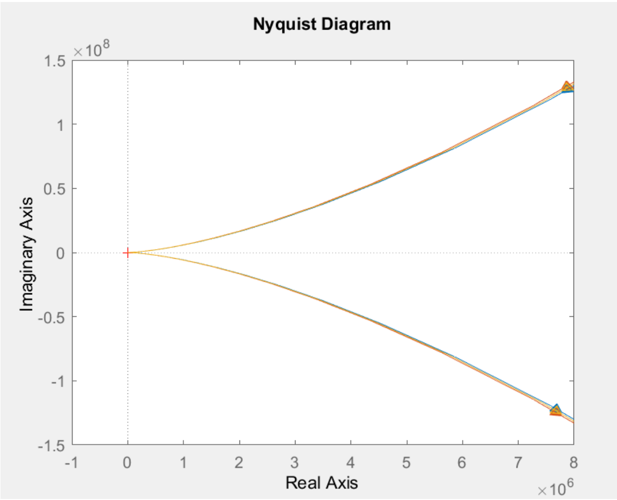
```
clear all;
close all;
clc;
k1=245;
k2=235;
k3=240;
num1=[k1];
num2=[k2];
num3=[k3];
den=[5 1 0 0];
func1=tf(num1,den);
func2=tf(num2,den);
func3=tf(num3,den);
nyquist(func1,func2,func3)
```



$$\text{IV. } L(s) = \frac{1}{s^3(1+T_1 s)}$$

Code:

```
clc;
clear all;
k1=245;
k2=235;
k3=240;
num1=[k1];
num2=[k2];
num3=[k3];
den=[5 1 0 0 0];
func1=tf(num1,den);
func2=tf(num2,den);
func3=tf(num3,den);
nyquist(func1,func2,func3);
```



Experiment-2

Aim: To plot the root locus for a given transfer function.

Software Used: Matlab

Theory: The Root locus is the locus of the roots of the characteristic equation by varying system gain K from zero to infinity. In the root locus diagram, we can observe the path of the closed loop poles. Hence, we can identify the nature of the control system. We know that, the characteristic equation of the closed loop control system is 1+G(s)H(s)=0
We can represent G(s)H(s) as G(s)H(s)=KN(s)/D(s)
K represents the multiplying factor, N(s) represents the numerator term having (factored) nth order polynomial of 's', D(s) represents the denominator term having (factored) mth order polynomial of 's'. Putting in equation 1,

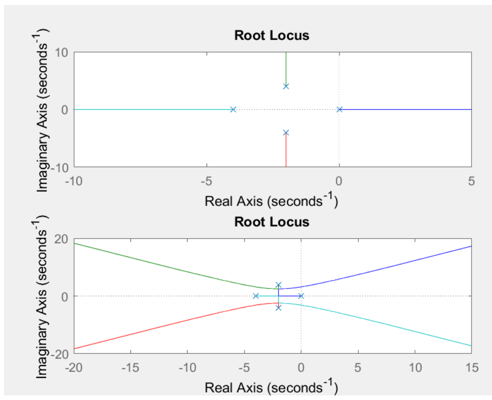
a)K=0: This means, the closed loop poles are equal to open loop poles when K is zero.

a)K = ∞: If K=∞, then N(s)=0. It means the closed loop poles are equal to the open loop zeros when K is infinity.

A.) G(s)H(s)=K/(s(s+4)(s^2+4s+20)

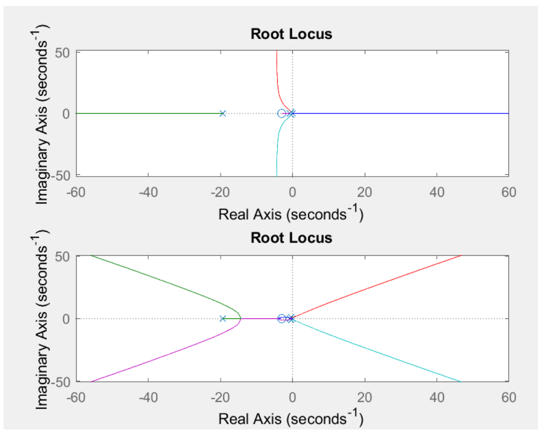
Code:

```
clear all;
close all;
clc;

k=[-3000,3000];
for i=1:2
    numerator=k(i);
    denominator=[1,8,36,80,0];
    sys=tf(numerator,denominator);
    display(sys)
    subplot(2,1,i);
    rlocus(sys);
end
```



B. G(s)H(s)=K(s+3)/(s(s+5)(s+6)(s2+2s+2))

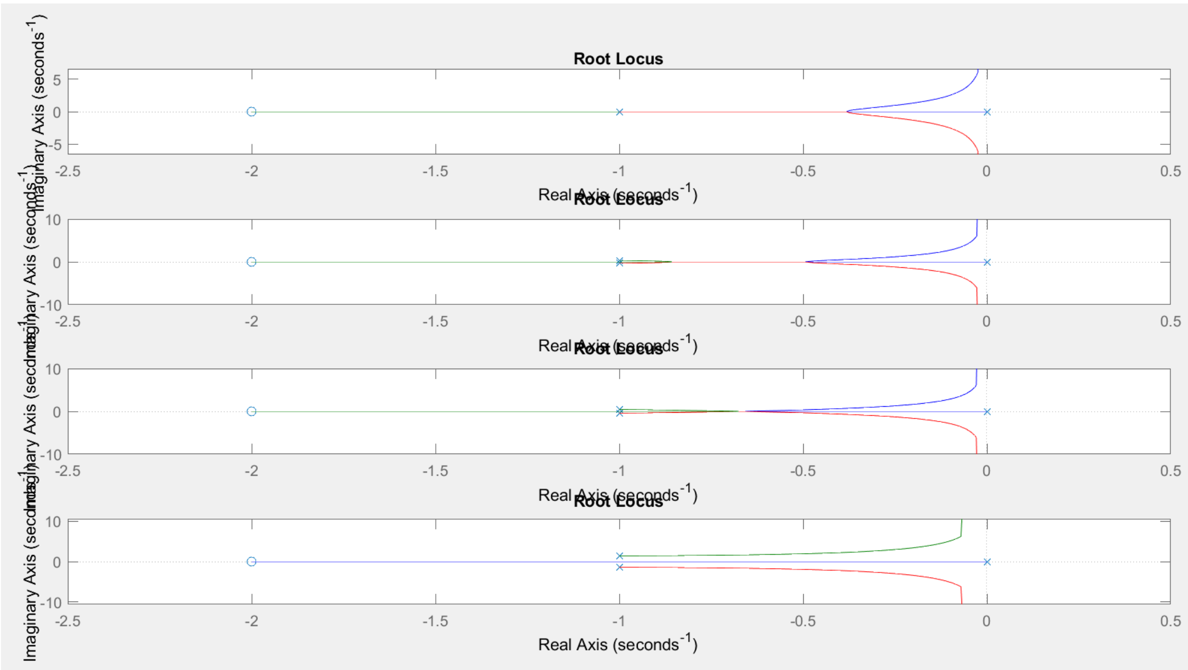
```
clear all;
close all;
clc;
k=[-3000,3000];
for i=1:2
    numerator=[k(i),3*k(i)];
    denominator=[1,21,35,44,22,0];
    sys=tf(numerator,denominator);
    display(sys)
    subplot(2,1,i);
    rlocus(sys);
end
```



C. G(s)H(s) = k(s+2)/(s(s2+2s+a)) for a = 1:1.12,1.185,3

Code:

```
clear all;
close all;
clc;
k=3000;
a = [1,1.12,1.185,3]
for j=1:4
    numerator=[k,2*k];
    denominator=[1,2,a(j),0];
    sys=tf(numerator,denominator);
    display(sys)
    subplot(4,1,j);
    rlocus(sys);
end
```



Experiment 3

Aim: To plot the step response for a given transfer function.

Software Used: Matlab

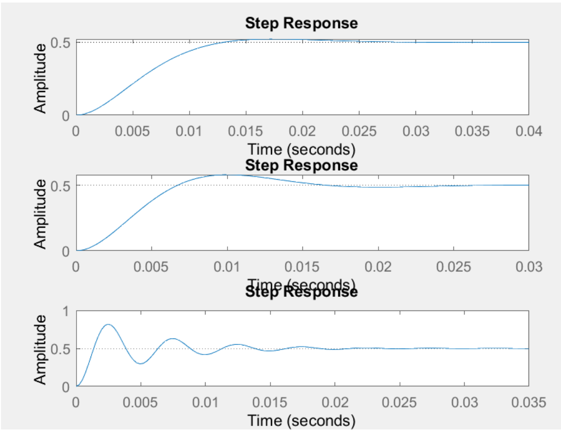
Theory: Step response is the time behaviour of the outputs of a general system when its inputs change from zero to one in a very short time. Let G(s) describe the system transfer function; then, the unit-step response is obtained as: (*s*)=*G*(*s*)1*s*y(s)=G(s)1s.

Its inverse Laplace transform leads to: (*t*)= L^{-1}(G(s)/s)

A.) G(s)=4500K/(s2 +361.2s+4500K) ;K=7.248;14.5;181.2

Code:

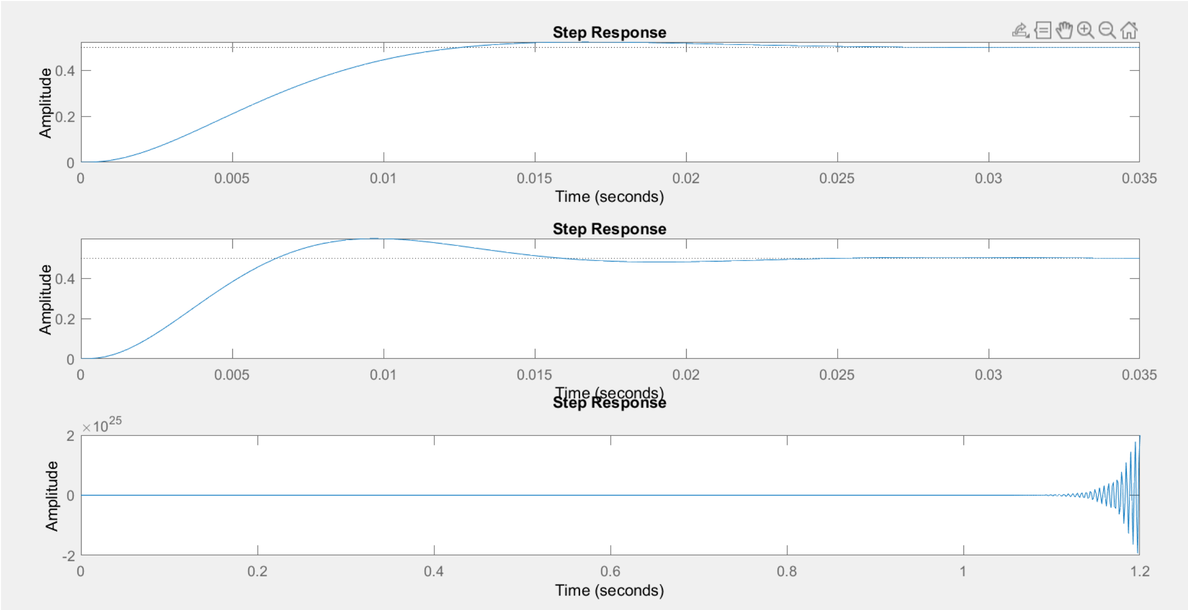
```
clear all;
close all;
clc;

k=[7.248,14.5,181.2];
for i=1:3
    numerator=4500*k(i);
    denominator=[1,361.2,4500*k(i)];
    sys=tf(numerator,denominator);
    sys=sys/(1+sys);
    subplot(3,1,i);
    step(sys);
end
```



B.) G(s) = 15000000*k / (s^3 + 3408.3s^2 + 1204000s + 15000000k) K=7.248;14.5;181.2

Code:

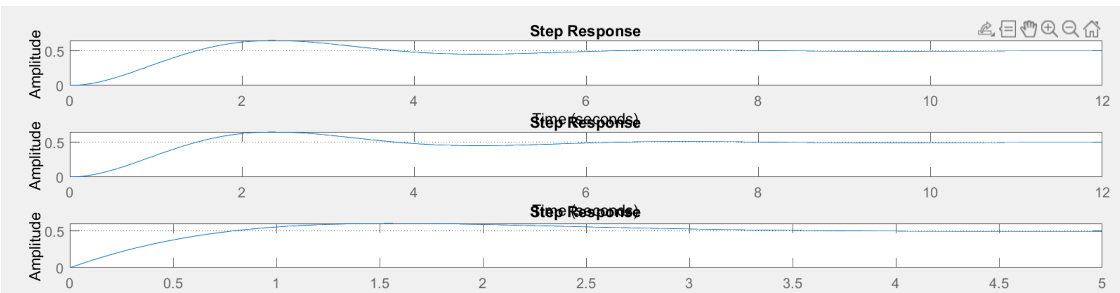
```
clear all;
close all;
clc;

k=[7.248,14.5,181.2];
for i=1:3
    numerator=15000000*k(i);
    denominator=[1,3408.3,1204000,15000000*k(i)];
    sys=tf(numerator,denominator);
    sys=sys/(1+sys);
    subplot(3,1,i);
    step(sys);
end
```

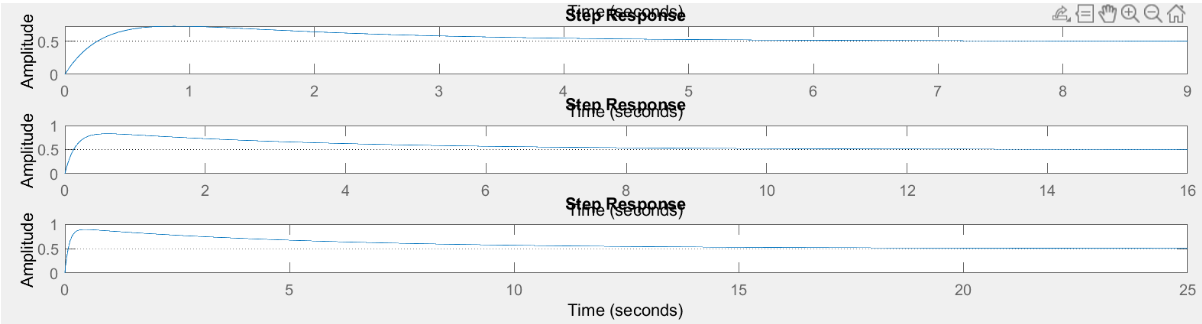


C.) G(s) = w2 / (s2 + 2Ews + w2), After Adding zero G(s) = w2(1+T2s) / (s2 + 2Ews + w2) where W = 1, E = 0.5, T2 = 0,1,3,6,10. Compare response of system with and without zero.

Code:

```
clear all;
close all;
clc;
w = 1;
E = 0.5;
%Without zero,
numerator = w^2;
denominator = [1,2*E*w,w^2];
sys=tf(numerator,denominator);
sys=sys/(1+sys);
subplot(6,1,1);
step(sys);
%With zero
T=[0,1,3,6,10];
for i=1:5
    numerator=[T(i)*w^2, w^2];
    denominator = [1,2*E*w,w^2];
    sys=tf(numerator,denominator);
    sys=sys/(1+sys);
    subplot(6,1,i+1);
    step(sys);
end
```

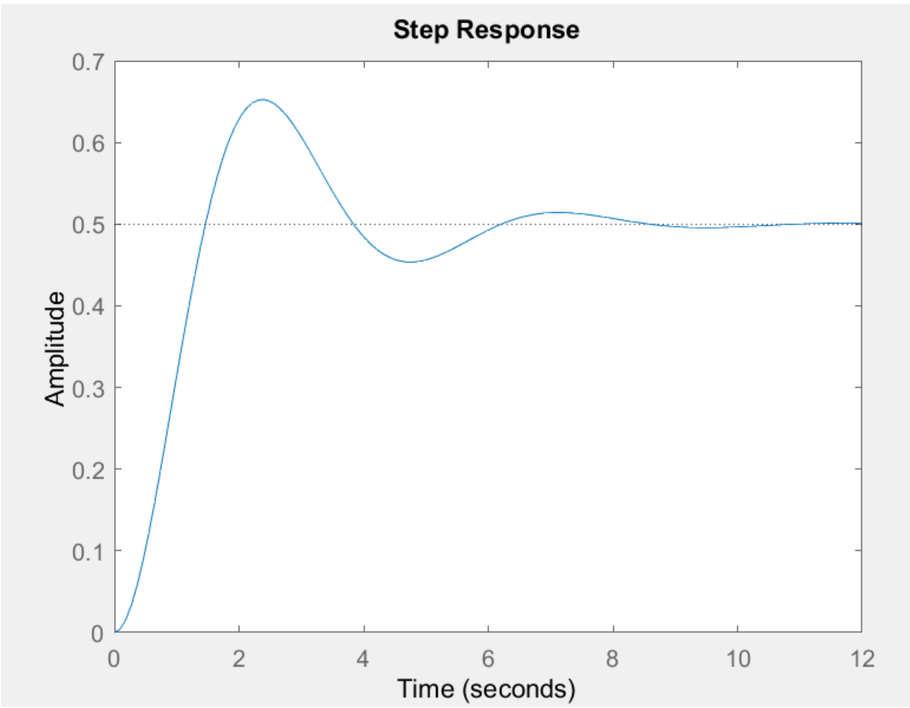




D.) $G(s) = \omega_n^2 / (s^2 + 2\xi\omega_n^2 + \omega_n^2)$; $\omega_n = 1$; $\xi = 0.5$; $T_2 = 0, 1, 3, 6, 10$

Code:

```
clc;
close all;
clear all;
numerator=1;
denominator=[1,1,2];
sys=tf(numerator,denominator);
display(sys);
subplot(1,1,1);
step(sys);
```



Conclusion: The step response for the given transfer function have been plotted.

Experiment 4

Aim: To show the bode plot and determine the given parameters.

Software Used: Matlab.

Theory: A Bode plot is a graph commonly used in control system engineering to determine the stability of a control system. A Bode plot maps the system's frequency response through two graphs – the Bode magnitude plot (expressing the magnitude in decibels) and the Bode phase plot (expressing the phase shift in degrees).

The greater the Gain Margin (GM), the greater the stability of the system. The gain margin refers to the amount of gain, which can be increased or decreased without making the system unstable. It is usually expressed as a magnitude in dB.

The formula for Gain Margin (GM) can be expressed as: $GM = 0 - G\ dB$

The greater the Phase Margin (PM), the greater will be the stability of the system. The phase margin refers to the amount of phase, which can be increased or decreased without making the system unstable. It is usually expressed as a phase in degrees.

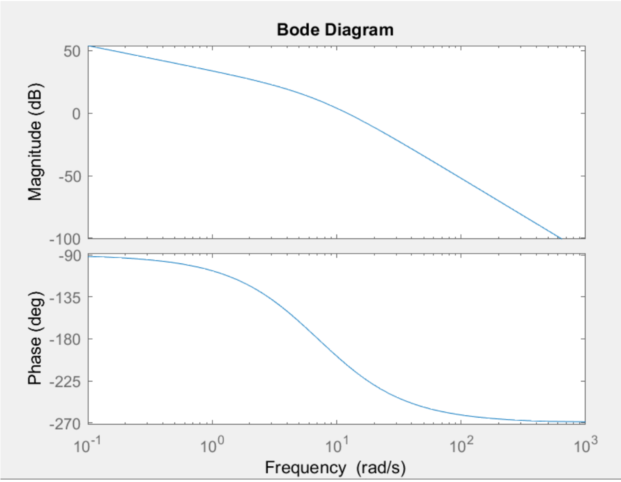
The formula for Phase Margin (PM) can be expressed as: $PM = \phi - (-180^\circ)$

a) $L(s) = \frac{2500}{s(s+5)(s+10)}$

- Find gain crossover frequency & phase margin.
- Find phase crossover frequency & gain margin.

Code:

```
clc;
close all;
clear all;
num=2500;
den = [1 15 50 0];
func = tf(num,den);
[GainMargin, PhaseMargin, PhaseCrossOverFrequency, GainCrossOverFrequency] = margin(func);
display("Gain Margin: " + GainMargin);
display("Phase Margin: " + PhaseMargin);
display("Gain Cross Over Frequency: " + GainCrossOverFrequency);
display("Phase Cross Over Frequency: " + PhaseCrossOverFrequency);
bode(func);
```



"Gain Margin: 0.3"

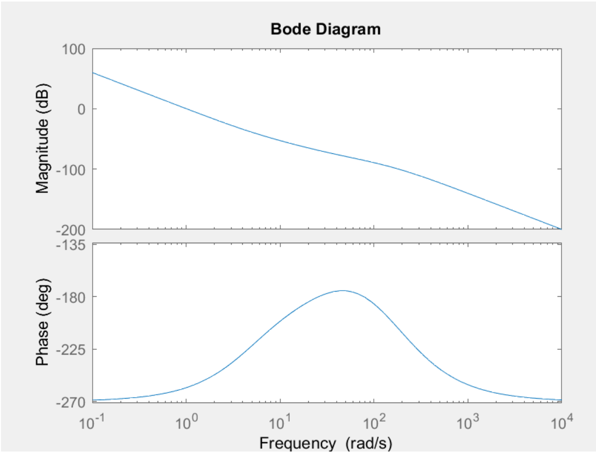
"Phase Margin: -28.0814"

"Gain Cross Over Frequency: 12.1263"

"Phase Cross Over Frequency: 7.0711"

b) $L(s) = \frac{100\,K\,(s+5)\,(s+40)}{s^3(s+100)(s+200)}$

```
clc;
close all;
clear all;
num=[100 4500 20000];
den = [1 300 20000 0 0 0];
func = tf(num,den);
[GainMargin, PhaseMargin, PhaseCrossOverFrequency, GainCrossOverFrequency] = margin(func);
display("Gain Margin: " + GainMargin);
display("Phase Margin: " + PhaseMargin);
display("Gain Cross Over Frequency: " + GainCrossOverFrequency);
display("Phase Cross Over Frequency: " + PhaseCrossOverFrequency);
bode(func);
```



"Phase Margin: 2847.8638"

"Gain Cross Over Frequency: 25.7438"

"Phase Cross Over Frequency: -78.0393"

Result: Greater will the phase margin greater will be the stability of the system. Hence, system 2 is more stable.