EE 324 Control Systems Lab

Problem Sheet 9

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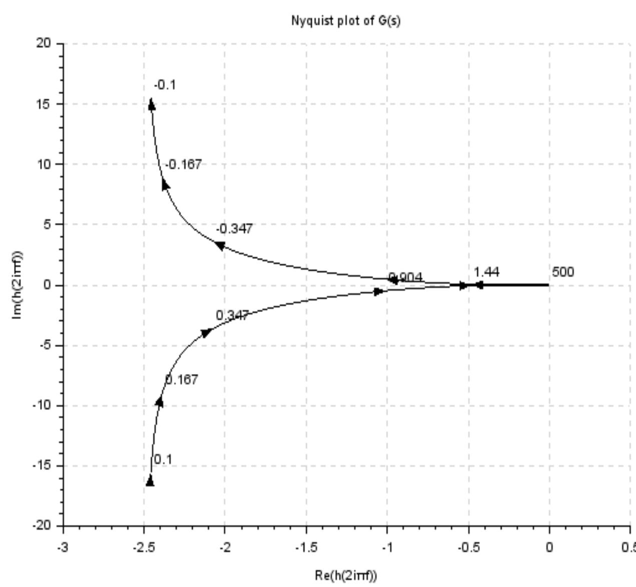
Question 1

We've been given an open loop transfer function,

$$G(s) = \frac{10}{s(s/5+1)(s/20+1)}$$

The Nyquist plot of G(s) using `SciLab` is,




```
s = poly(0, 's');
G = syslin('c', 10/(s*((s/5)+1)*((s/20)+1)));
nyquist(G, 0.1, 500);
g_margin(G)
p_margin(G)
```

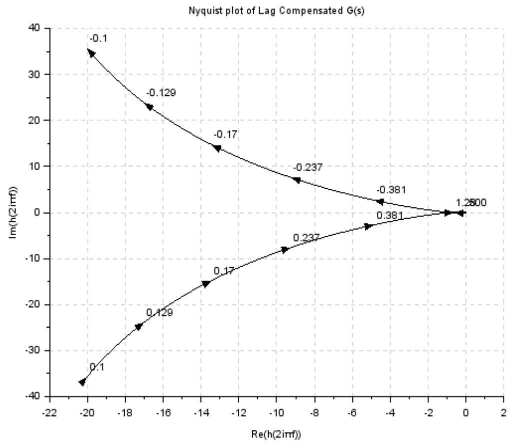
Part (i) :

C(s) is a Lag Compensator

$$C(s) = \frac{s+3}{s+1}$$

$$\implies G_{LagComp} = C(s)G(s) = \frac{10(s+3)}{s(s+1)(s/5+1)(s/20+1)}$$

The Nyquist plot of G_LagComp using `SciLab` is,



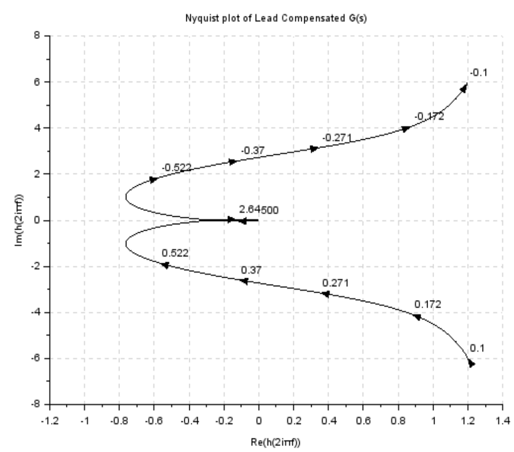

```
Lag_Comp = G*(s+3)/(s+1);
G_LagComp = syslin('c', Lag_Comp);
scf();
nyquist(G_LagComp, 0.1, 500);
g_margin(G_LagComp)
p_margin(G_LagComp)
```

Part (ii) :
C(s) is a Lead Compensator

$$C(s) = \frac{s+1}{s+3}$$

$$\implies G_{LeadComp} = C(s)G(s) = \frac{10(s+1)}{s(s+3)(s/5+1)(s/20+1)}$$

The Nyquist plot of G_LeadComp using `SciLab` is,




```
Lead_Comp = G*(s+1)/(s+3);
G_LeadComp = syslin('c', Lead_Comp);
scf();
nyquist(G_LeadComp, 0.1, 500);
g_margin(G_LeadComp)
p_margin(G_LeadComp)
```

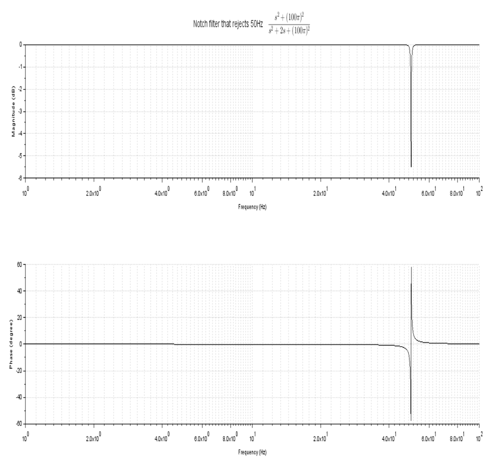
System	Gain Margin (in dB)	Phase Margin (in degrees)
$G_{LeadComp}(s)$	11.7595	43.1731
G(s)	7.9588	22.5359
$G_{LagComp}(s)$	2.0762	4.0427

Question 2

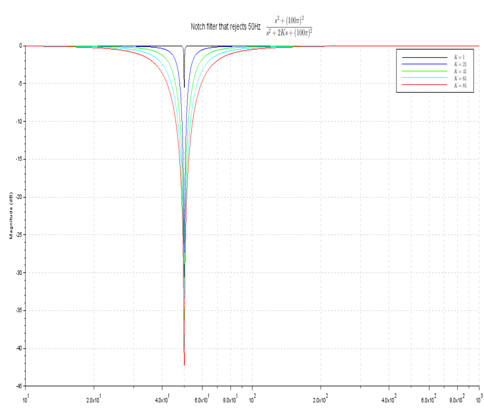
Notch filter system that rejects 50Hz signal is,

$$G(s) = \frac{s^2 + (100\pi)^2}{s^2 + 2s + (100\pi)^2}$$

Bode plot of G(s) using `SciLab` is,



Now, we will vary gain K of the closed loop transfer function of G(s)



The steepness of the magnitude plot can be controlled by varying the real part of the poles of the transfer function. If the real part of the poles is far away from the origin, the steepness reduces.

```
s = poly(0, 's');
G = syslin('c', ((s^2+(100*%pi)^2)/(s^2 + 2*s + (100*%pi)^2)));
scf();
bode(G, 1, 100);
K = 1:20:100;
tfs = [];
labels = [];
```

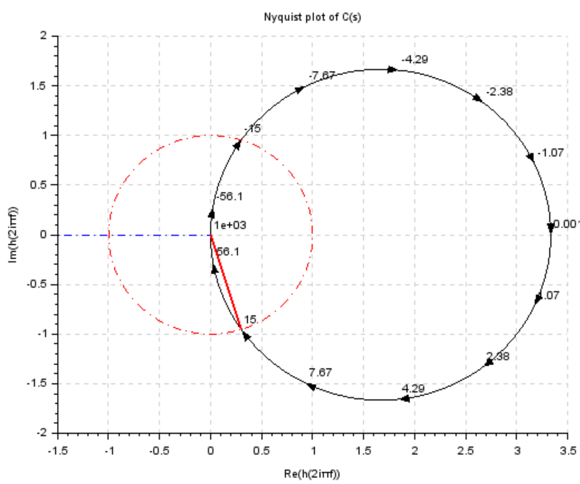
```
for i=1:size(K, 2)
    k = K(i);
    G = syslin('c', ((s^2+(100*%pi)^2)/(s^2 + 2*k*s + (100*%pi)^2)));
    tfs = [tfs; G];
    str = sprintf("$K = %d$", k);
    labels = [labels; str];
end
scf();
gainplot(tfs, 10, 1000, labels);
```

Question 3

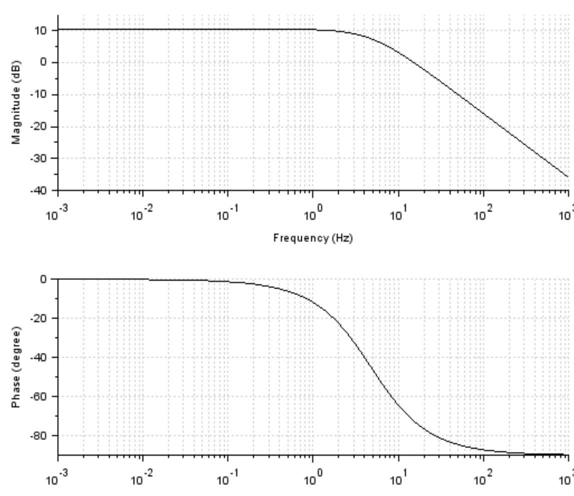
System given to us is,

$$C(s) = \frac{100}{s+30}$$

Nyquist plot of the system using `SciLab`,



Bode plot of the system using `SciLab`,



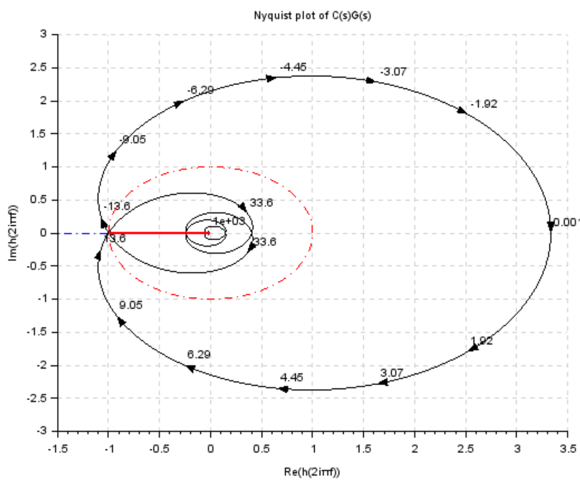
From the Nyquist diagram, we can conclude that the gain margin of C(s) is 0dB and the phase margin is 107.45760312 degrees with gain crossover frequency of 15.18241393 Hz. Hence, the minimum delay required to destabilize the closed-loop system is,

$$T = \frac{PM}{\omega_{gcf}} = 0.01966s$$

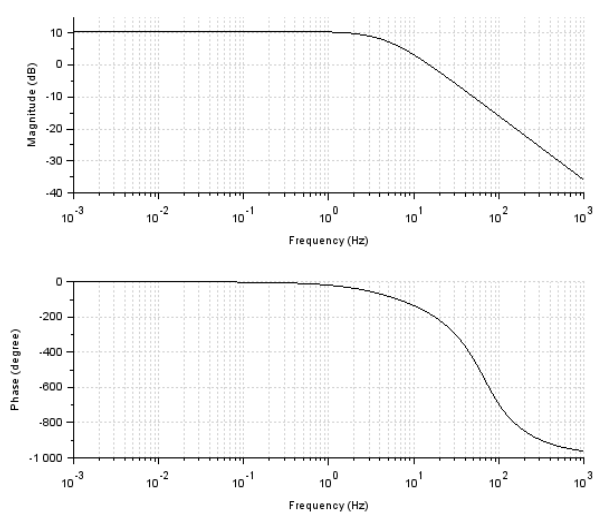
Using Pade's approximation to model e^{-sT},

$$e^{-sT} \approx \frac{1 - 0.5sT + (1/9)(sT)^2 - (1/72)(sT)^3 + (1/1008)(sT)^4 - (1/30240)(sT)^5}{1 + 0.5sT + (1/9)(sT)^2 + (1/72)(sT)^3 + (1/1008)(sT)^4 + (1/30240)(sT)^5}$$

The Nyquist diagram of C(s)G(s) where G(s) is the delay using `SciLab` is,



The Bode diagram of C(s)G(s) where G(s) is the delay using `SciLab` is,



The new phase margin is now 0.00000529 and the new gain margin is 0.07814458dB.

```
s = poly(0, 's');
C = syslin('c', 100/(s+30));
[Phase_m, fm] = p_margin(C)
g_margin(C)
Phase_m
fm
```

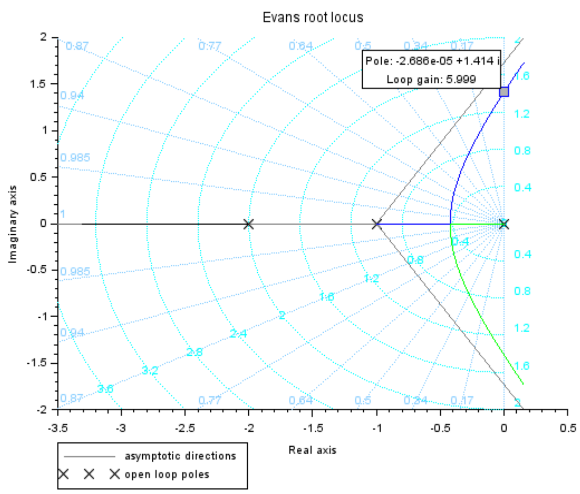
```
scf();
show_margins(C, 'nyquist');
T = Phase_m*(%pi/180)/(2*%pi*fm);
CG = syslin('c', C*(1-0.5*s*T+(1/9)*(s*T)^2-(1/72)*(s*T)^3+(1/1008)*(s*T)^4
-(1/30240)*(s*T)^5)/(1+0.5*s*T+(1/9)*(s*T)^2+(1/72)*(s*T)^3+(1/1008)*(s*T)^4+(1/30240)*(s*T)^5));
scf();
show_margins(CG, 'nyquist');
g_margin(CG)
p_margin(CG)
scf();
bode(C);
scf();
bode(CG);
```

Question 4

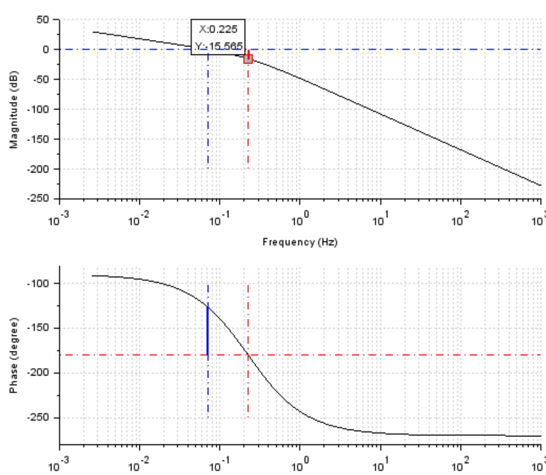
Given open loop transfer function is,

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

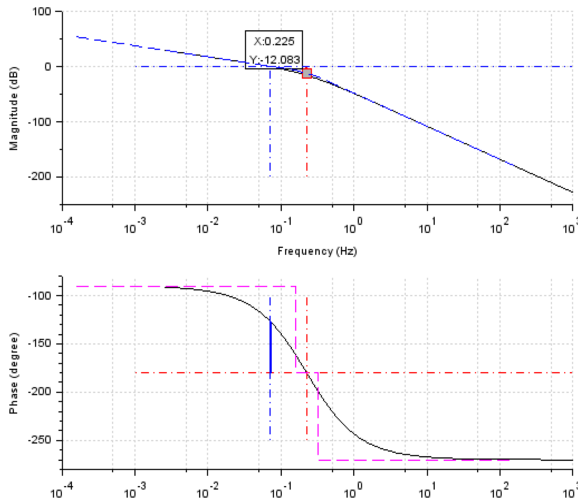
Root Locus of the given system using `SciLab` is,



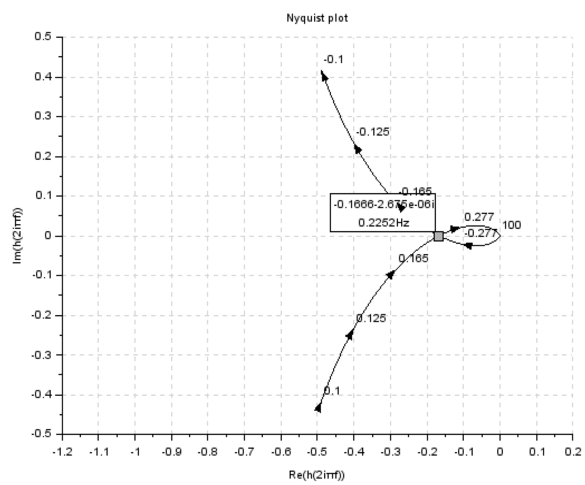
Bode Plot of the given system using `SciLab` is,



Asymptotic Bode Plot of the given system using `SciLab` is,



Nyquist Plot of the given system using `SciLab` is,



Technique	Gain Margin (in dB)
Root Locus	15.5616
Bode Plot	15.565
Asymptotic Bode Plot	12.803
Nyquist Plot	15.5665

```
s = poly(0, 's');
G = syslin('c', 1/(s^3 + 3*s^2 + 2*s));
Kr = kpure(G);
Gain_m = 20 * log(Kr) / log(10);
Gain_m
scf();
evans(G, 10);
sgrid;
scf();
show_margins(G, 'bode');
scf();
```

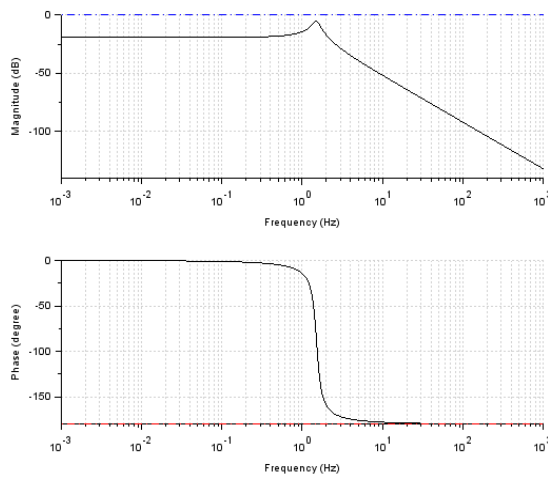
```
bode_asymp(G);
scf();
nyquist(G, 0.1, 100);
```

Question 5

Given open loop transfer function is,

$$G(s) = \frac{10s + 2000}{s^3 + 202s^2 + 490s + 18001}$$

Bode Plot of the given system using `SciLab` is,



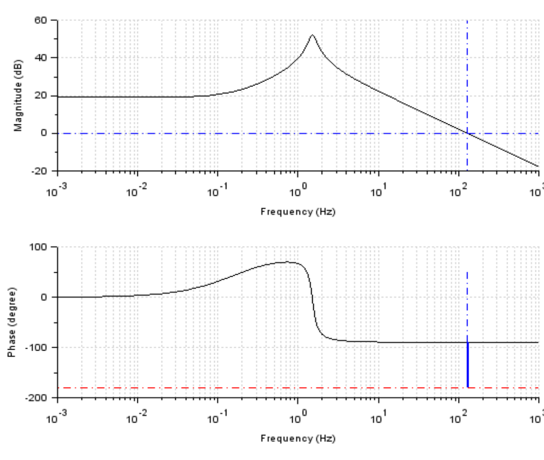
The Gain Margin is infinity and the Phase Margin is not defined.
To get the steady state error as 10%, the proportional gain K = 81.0045.
Hence,

$$G1(s) = \frac{81.0045(10s + 2000)}{s^3 + 202s^2 + 490s + 18001}$$

The gain margin for G1 is also infinity and the phase margin is 4.24260124 degrees and the gain crossover frequency is 4.76888914Hz. To improve the phase margin of G1 such that the new phase margin is greater than or equal to 90 degrees, without altering the dc gain, we cascade G1 with s+1.

$$G1(s) = \frac{81.0045(10s + 2000)(s + 1)}{s^3 + 202s^2 + 490s + 18001}$$

As we are adding a unit zero, this does not alter the dc gain.
The Bode plot of the modified system using `SciLab` is,



The new gain margin is 0dB, phase margin is 90.07074111 degrees and the gain crossover frequency is 128.94005171Hz. The closed loop poles of the modified system are -810.93512,-199.99999,-1.1098916. Hence, it is closed-loop stable.

References

1) https://help.scilab.org/
2) https://spoken-tutorial.org/tutorial-search/?search_foss=Scilabsearch_language=English
3) https://spoken-tutorial.org/tutorial-search/?search_foss=Scilabsearch_language=Englishpage=2