YTU ELECTRICAL & ELECTRONICS FACULTY
DEPARTMENT OF CONTROL & AUTOMATION ENGINEERING
KOM3712 CONTROL SYSTEM DESIGN, Midterm Exam

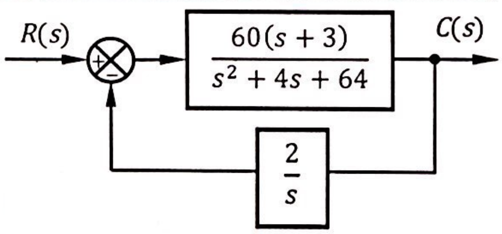
Name and Surname:		Grades:	
Student number:		Problem-1.	20
Signature:	Date: April 10, 2019	Problem-2.	30
		Problem-3.	30
	Duration: 80 mins.	Problem-4.	20

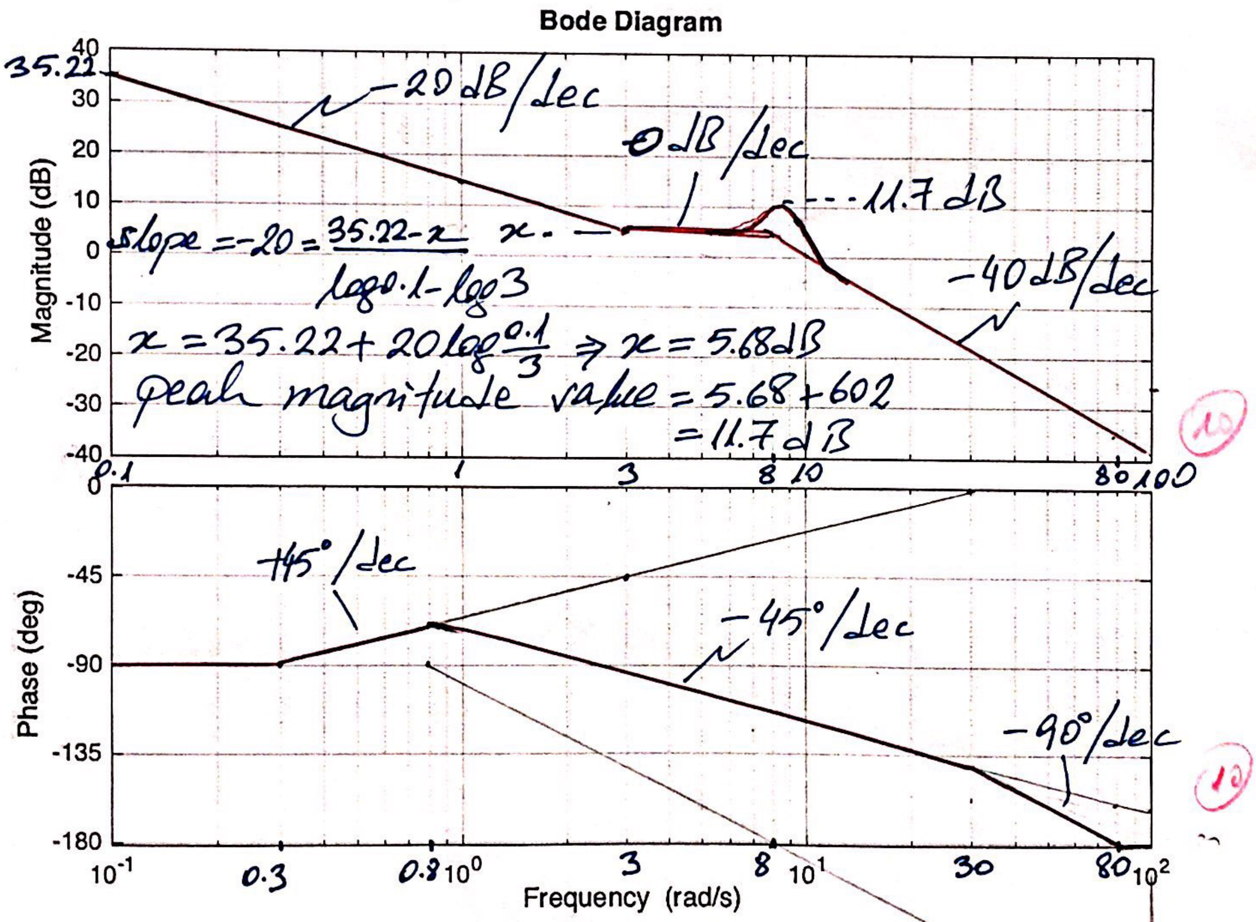
Problem-1. Considering the feedback system on the right,

(a) Sketch the Bode magnitude and phase plots with asymptotes on the logarithmic planes provided.

(b) Write the slopes of each asymptotes on the plots.

(c) Calculate the correction value in dB and show it on the magnitude plot for the underdamped components.





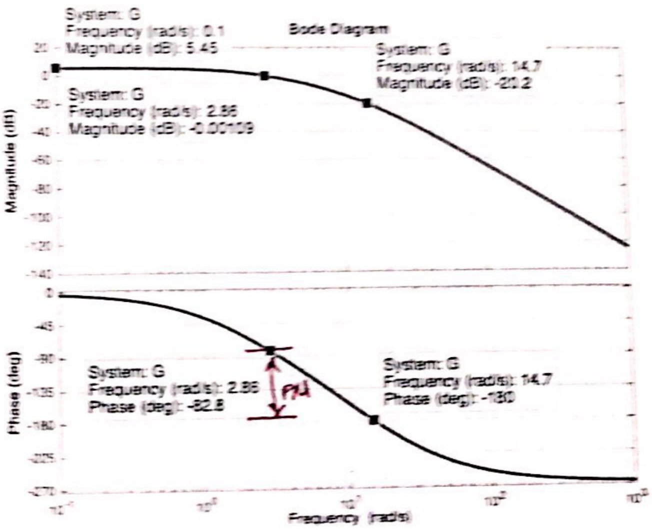
Solution-1.

Open-loop transfer function: $G(s)H(s) = \frac{120(s+3)}{s(s^2+4s+64)} = \frac{120\cdot 3(s/3+1)}{64s\left(s^2/_{64} + 4/_{64}s + 1\right)}$

The contribution of $\frac{120\cdot 3}{64s} = \frac{5.7656}{s}$; the magnitude at $\omega = 1$ ➔ $20\cdot\log 5.7656 = 15.22$ dB and at $\omega = 0.1$, the magnitude will be 35.22 dB

$s^2 + 4s + 64$ ➔ $\omega_n = 8$ rad/s, $\zeta = 0.25$ ➔ $Correction = 20\cdot\log 2\zeta = 6.02$ dB

Problem-2. For the Bode plots on the right, which were obtained experimentally from a subsystem $G(s)$ for the gain K=600,



(a) Determine the Gain Margin in dB,

(b) and Phase Margin in degrees when it is connected to a feedback system.

(c) What is the value of gain, K_{cr}, that makes the system marginally stable?

(d) What would be the period of oscillation, T_{cr}, in sec at this gain?

(e) Write the range of gain K to keep the system stable.

(f) Determine the system type then find the appropriate static error constant and the corresponding steady state error.

Solution-2

a) $GM = 20.2\,dB$

b) $PM = -82.8° - (-180°) \Rightarrow PM = 97.2°$

c) $20 \log x = 20.2\,dB \Rightarrow x = 10^{20.2/20} = 10.233$

$K_{cr} = K \cdot x = 600 * 10.233 \Rightarrow K_{cr} \cong 6140$ (6139.8)

(d) $W_{cr} = 14.7\ rad/s = \frac{2\pi}{T_{cr}}$

$T_{cr} = \frac{2\pi}{14.7} = 0.43$ sec

(e) $0 < K < K_{cr} \Rightarrow 0 < K < 6140$

(f) Type 0 (initial slope is 0 dB/dec)

$20 \log K_p = 5.45 \Rightarrow K_p = 1.873$

$e_{ss} = \frac{1}{1+K_p} = 0.348$ per unit step

(a) > 5
(b)
(c) — 10
(d) 2
(e) 3
(f) — 10

30

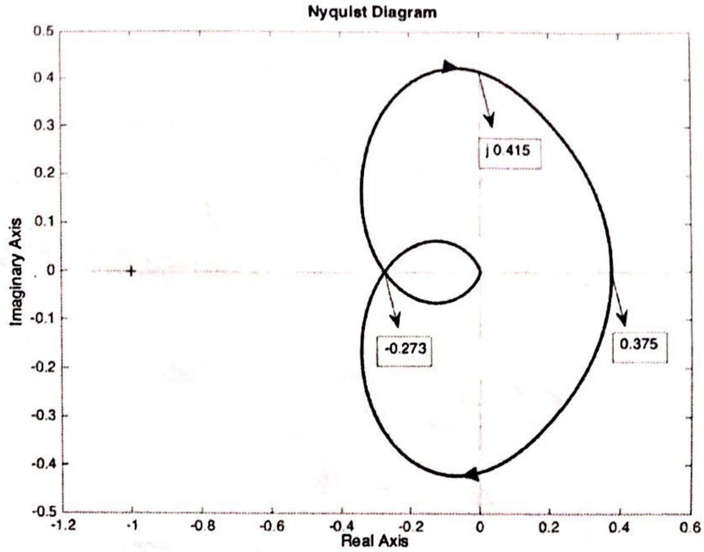
Problem-3. Suppose that the Nyquist diagram on the right is for an open-loop transfer function of a feedback control system when the gain is K=120.

(a) Find the range of gain K for stability using the Nyquist criterion.

(b) Find the Gain Margin in dB.

(c) What would be value of gain to get a gain margin of 20 dB?

(d) What would be the real-axis crossings value at that gain?



Solution-3

(a) $K_{cr} = \left|\frac{1}{-0.273}\right| * 120 = 439.56 \Rightarrow K_{cr} \approx 440$

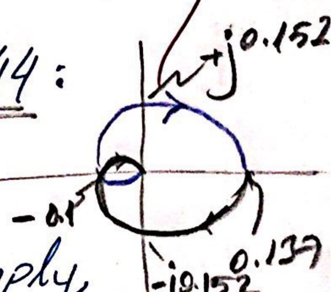
Stability range for K: $0 < K < 440$

(b) $GM = 20\log\left|\frac{1}{-0.273}\right| \Rightarrow GM = 11.28$ dB

(c) $20\log x = 20$ dB $\Rightarrow x = 10^{20/20} = 10$

The gain value for this $GM = 440/10 = 44$

(d) Real-axis crossings for $K = 44$:



for $K = 120 \rightarrow Re() = -0.273$

$= 44 \rightarrow x_1$

* $x_1 = -0.273\,\frac{44}{120} = -0.1$

* $x_2 = 0.375\,\frac{44}{120} = 0.137$

Or simply, for full range,

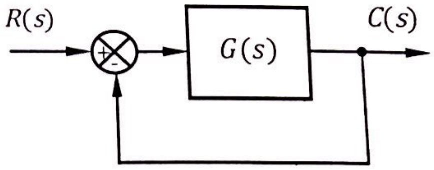
$K = 440 \Rightarrow Re = -1$

$= 44 \rightarrow -1/10 = -0.1$

Imag-axis crossings for $K = 44$: $y_{1,2} = \pm j0.415\,\frac{44}{120} = \pm j0.152$

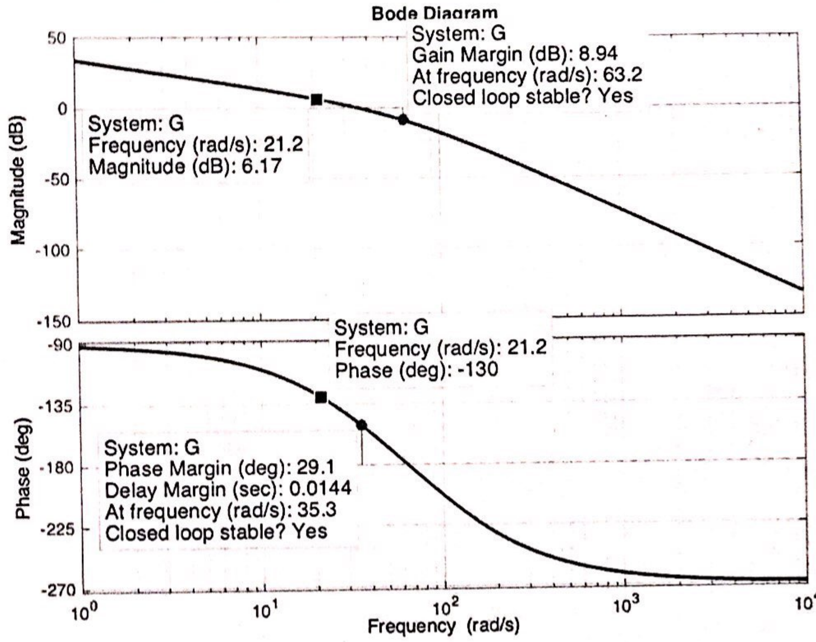
(a) 10
(b) 5
(c) 10
(d) 5
30

Problem-4. Considering the unity feedback system on the RHS, where the open-loop transfer function is,



$$G(s) = \frac{200{,}000}{s(s+40)(s+100)}$$

$G(s)$ has the following Bode plots. As the phase margin indicates, the system produces a very high percent overshoot (over 40%). Determine the value of gain, K, to increase the phase margin to 50° so that the closed-loop step response can produce below 20% overshoot ($\zeta = 0.48$).



Solution-4

New PM = 50° ⇒ $\phi_{new} = -130°$ @ $\omega = 21.2$ rad/s.

at this frequency $M = 6.17$ dB

This magnitude should be lowered to 0 dB to accomplish $\phi_{new} = -130°$ & PM = 50°

$20 \log x = 6.17$

$x = 10^{6.17/20} = 2.035$

So the new gain should be 200,000/2 ($K_{old}/2$) ⇒ $K = 100{,}000$