In-Class Exercise #5 ECE 345 M. Ojishi

12/12

Pre-class

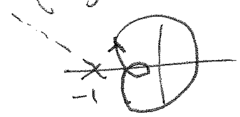
1. Type # of $\frac{Y(s)}{R(s)}$ is 1 since $G(s)$ has one pole at origin.

2. $\Delta(s) = s(s+2)(s+10) + K \cdot 10$

$= s^3 + 12s^2 + 20s + K \cdot 10$

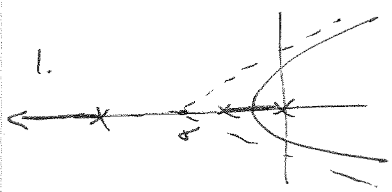
3. See attached pages.

4. $N = 0$.



In-class

1.



$\sigma = \frac{-(0+2+10)}{3} = -4$, $\phi = \pm 60°, 180°$.

$\rightarrow$ (a) + (d) are correct.

2. $\Delta(s) = (s^2 + w^2)(s + a)$

$s^3 + 12s^2 + 20s + K \cdot 10 = s^3 + as^2 + w^2 s + w^2 a$

$\Rightarrow 12 = a, \quad 20 = w^2, \quad K \cdot 10 = w^2 a$

$K = \frac{(20)(12)}{10} = 24.$

3. See attached plot.

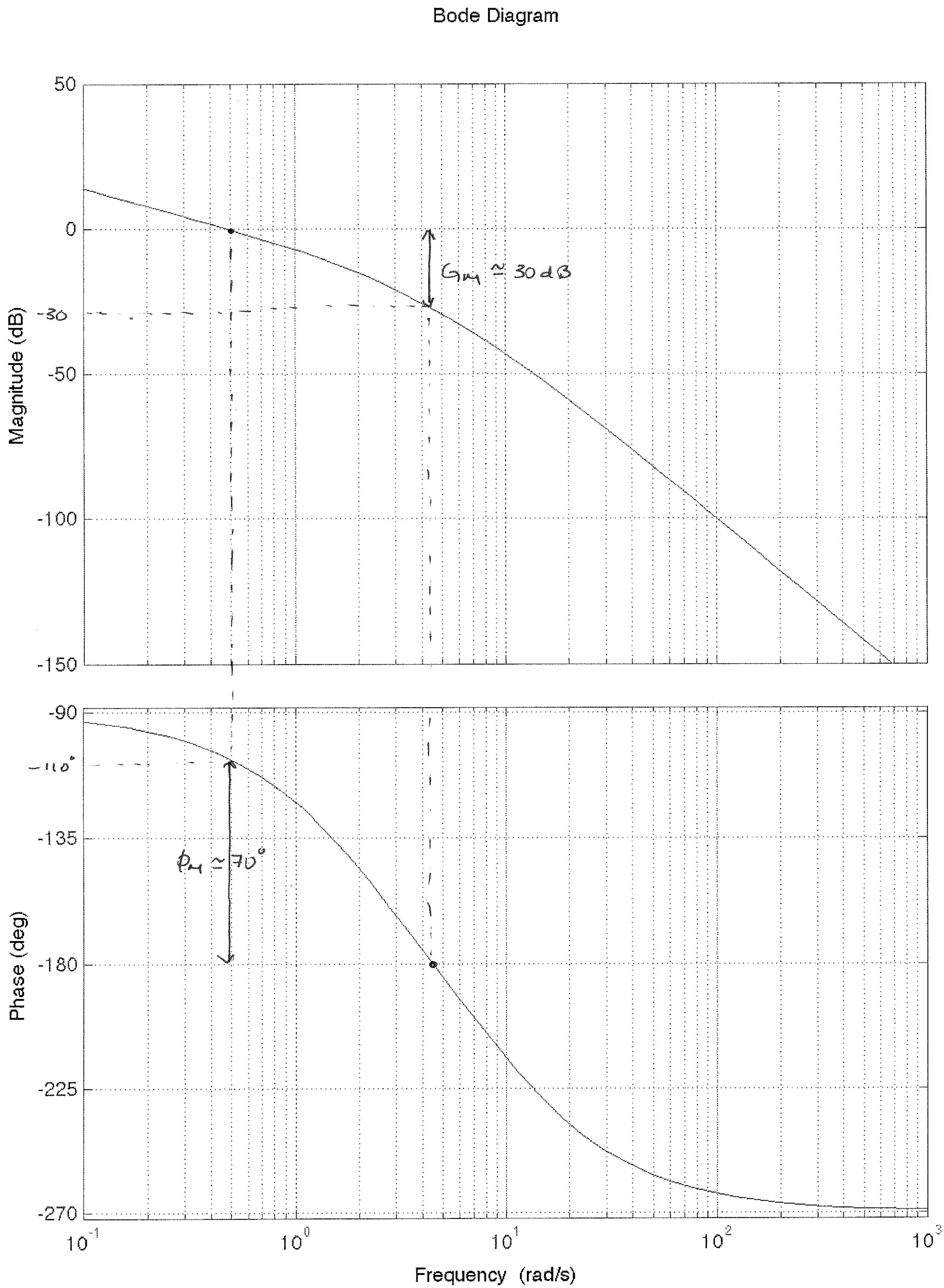
4. $GM \approx 25$.

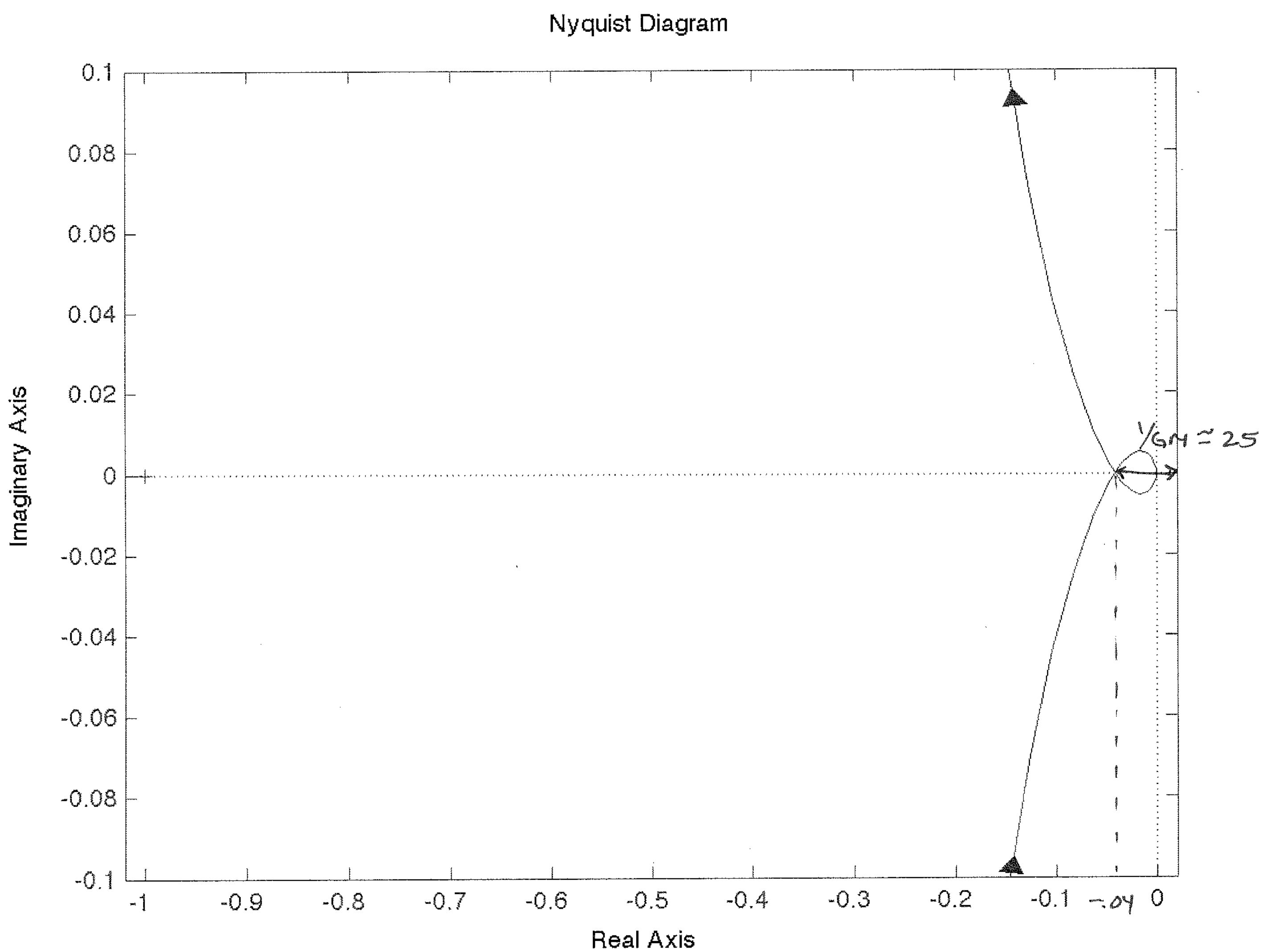
5. (a) Gain margin + calculation of K that destabilizes the system are the same. Discrepancies based on plots are due to estimation errors.

6. Mathematically, $0 < K < 24$ will meet stability criteria. However, due to modeling errors + disturbance forces, choosing poles extremely close to the imaginary axis is not a good idea.

Often, $20^\circ - 30^\circ$ Φ_M is a good idea. The gain required to shift the magnitude curve up such that $\Phi_M = 30^\circ$ is approximately $10\,dB \equiv K = 3$.

Hence $0 < K < 3$ is a more practical range of K, and $K = 3$ to achieve $\Phi_M = 30^\circ$.


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/s)
50
0
-50
-100
-150
-90
-135
-180
-225
-270
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
-30
-110°
$G_M \simeq 30\,dB$
$\phi_M \simeq 70°$


Nyquist Diagram
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
Imaginary Axis
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
-.04
0
Real Axis
1/GM ≈ 25