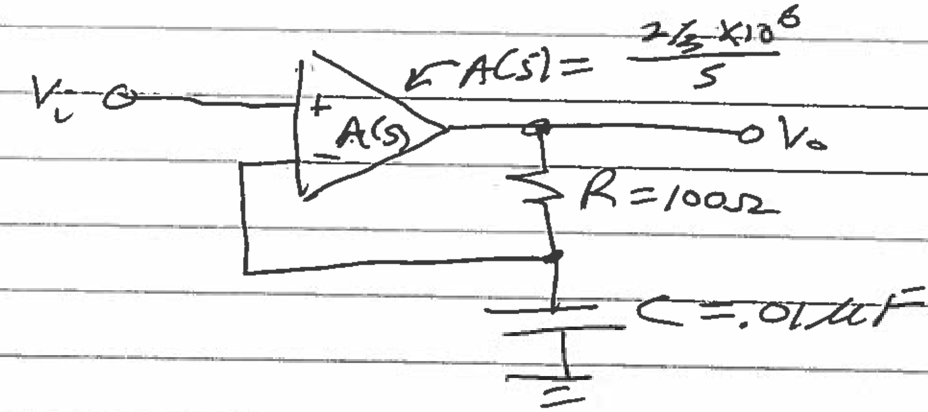
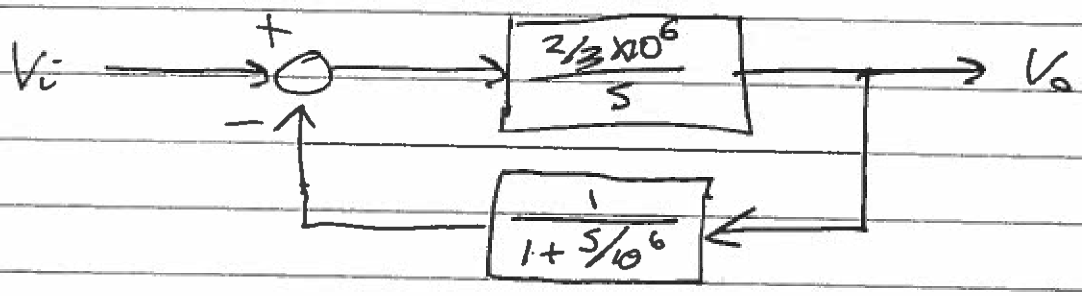
EE352 HW6 Solutions

1.



⇓ converts to



a.) $LG(s) = A(s)\,\beta(s) = \frac{2/3 \times 10^6}{s(1+s/10^6)}$

$$PM = 180^\circ - |\measuredangle LG(j\omega_1)|$$

$$\measuredangle LG(j\omega_1) = -90^\circ - \tan^{-1}\frac{\omega_1}{10^6}$$

$$|LG(j\omega_1)| = 1 = \frac{2/3 \times 10^6}{\omega_1\left[1+\left(\frac{\omega_1}{10^6}\right)^2\right]^{1/2}}$$

$$\therefore\quad 1 = \frac{4/9 \times 10^{12}}{\omega_1^2\left[1+\frac{\omega_1^2}{10^{12}}\right]}$$

$$\therefore\quad \frac{\omega_1^4}{10^{12}} + \omega_1^2 - 4/9 \times 10^{12} = 0$$

$$\Rightarrow \omega_1 = \frac{-1 \pm \sqrt{1+16/9}}{2 \times 10^{-12}}$$

$$\Rightarrow \omega = \frac{1}{\ldots} \times 10^6 \text{ rad/sec}$$

$\therefore \measuredangle\, \angle G(j\omega_1) = -90^\circ - \tan^{-1}\frac{1}{\sqrt{3}} = -120^\circ$

$$\boxed{\therefore PM = 180^\circ - |-120^\circ| = 60^\circ}$$

b.) See ~~attached~~ next pages for matlab

c.) $T(s) = A_f(s) = \dfrac{A(s)}{1 + A(s)\beta(s)}$

$$= \frac{\frac{2}{3}\times 10^6/s}{1 + \dfrac{2/3 \times 10^6}{s(1 + s/10^6)}}$$

$$\boxed{T(s) = \frac{1 + s/10^6}{\dfrac{s^2}{\frac{2}{3}\times 10^{12}} + \dfrac{s}{\frac{2}{3}\times 10^6} + 1}}$$

pzmap(T) → See next pages for matlab

bode(T) → See next pages for matlab

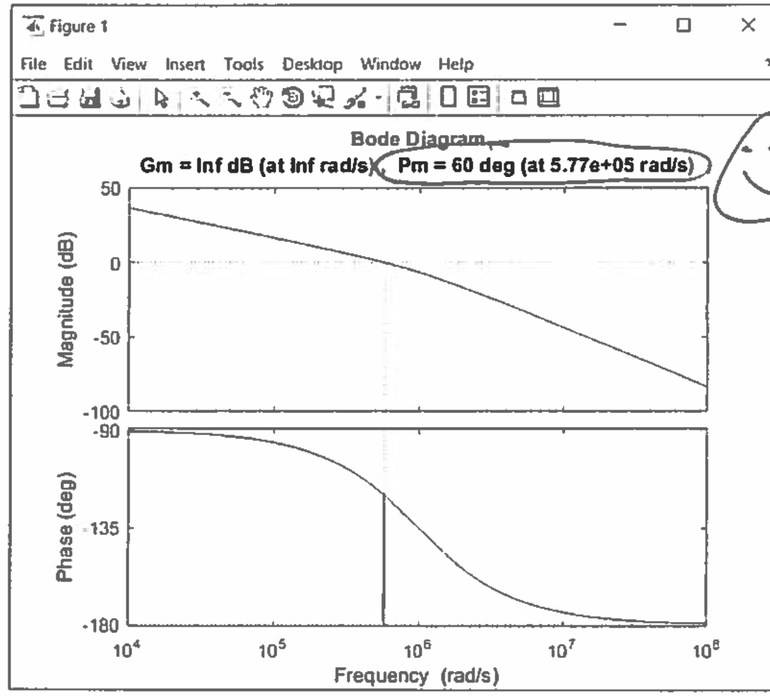
d.) step(T) → See next pages for matlab

1b.)

Command Window

New to MATLAB? See resources for Getting Started.

```
A =

  6.667e05
  --------
     s

Continuous-time transfer function.

>> B=1/(1+s/1e6)

B =

    1e06
  --------
  s + 1e06

Continuous-time transfer function.

>> LG=A*B

LG =

     6.667e11
  ------------
  s^2 + 1e06 s

Continuous-time transfer function.

>> margin(LG)
```



Name	Value
A	1x1 tf
Af	1x1 tf
B	1x1 tf
LG	1x1 tf
s	1x1 tf

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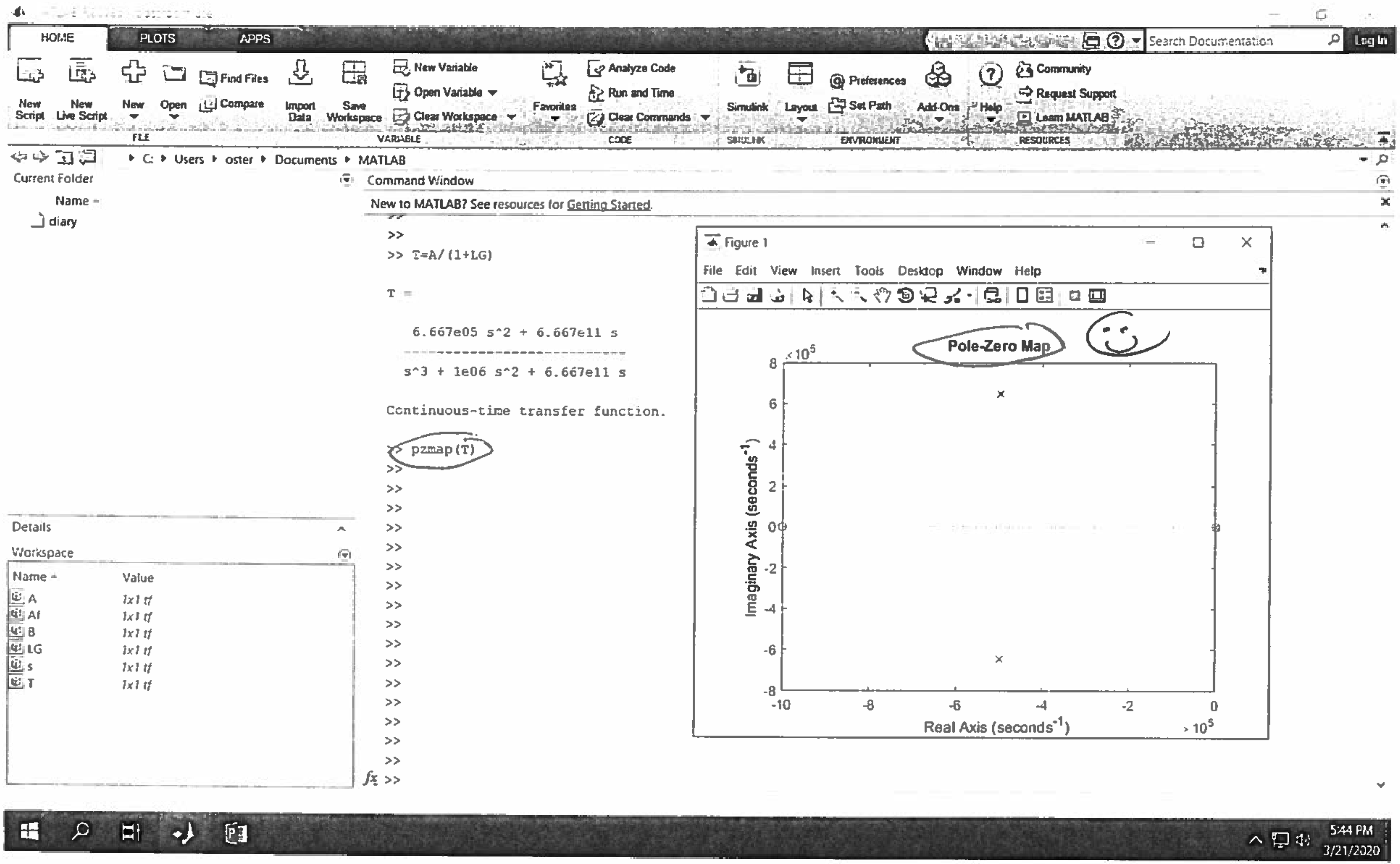
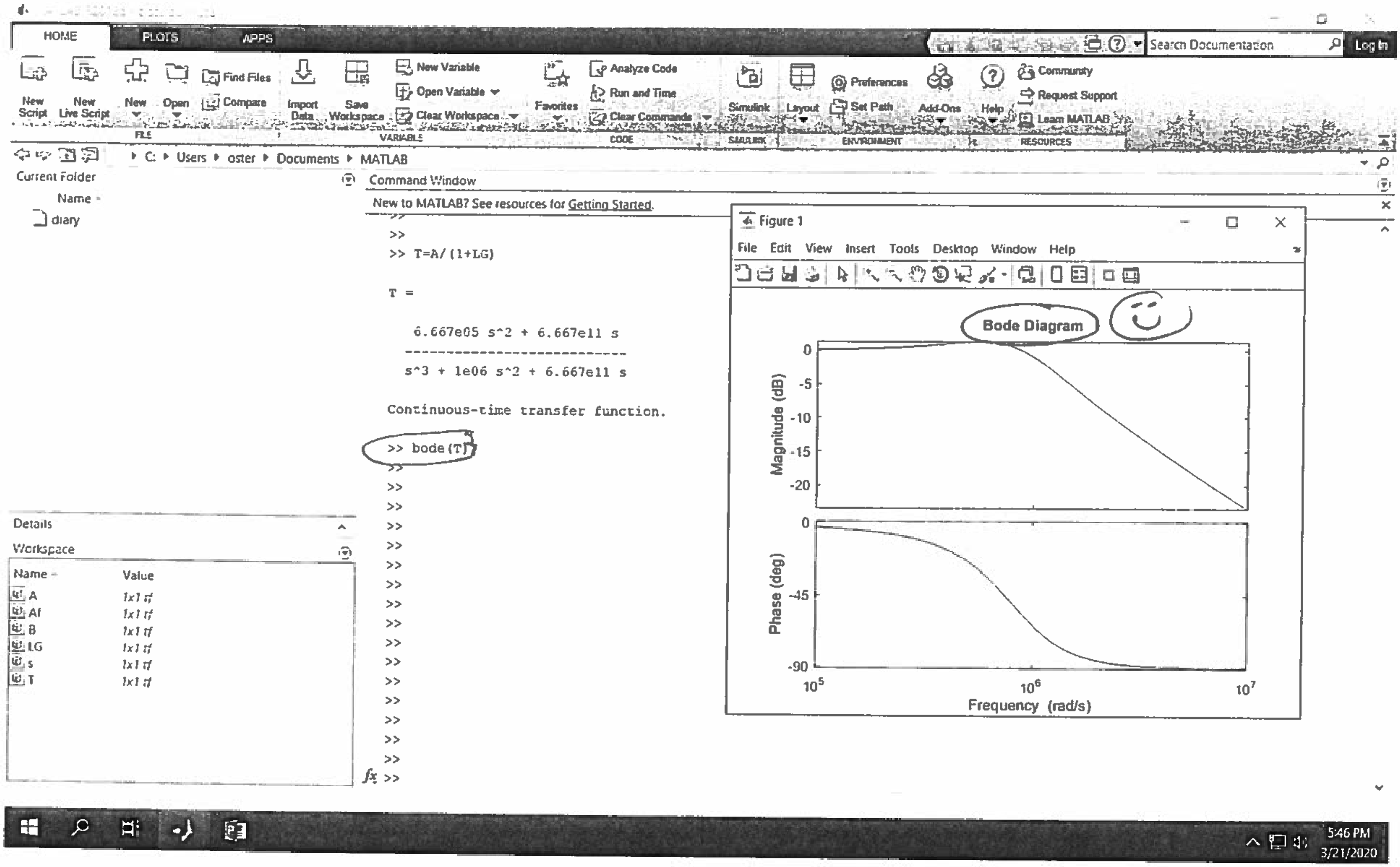
1.c.)


HOME
PLOTS
APPS
Search Documentation
Log In
New Script
New Live Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Favorites
Analyze Code
Run and Time
Clear Commands
Simulink
Layout
Preferences
Set Path
Add-Ons
Help
Community
Request Support
Learn MATLAB
FILE
VARIABLE
CODE
SIMULINK
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ oster ▸ Documents ▸ MATLAB
Current Folder
Name
diary
Command Window
New to MATLAB? See resources for Getting Started.
>>
>> T=A/(1+LG)
T =
6.667e05 s^2 + 6.667e11 s
----
s^3 + 1e06 s^2 + 6.667e11 s
Continuous-time transfer function.
>> pzmap(T)
Details
Workspace
Name
Value
A
1x1 tf
Af
1x1 tf
B
1x1 tf
LG
1x1 tf
s
1x1 tf
T
1x1 tf
Figure 1
File
Edit
View
Insert
Tools
Desktop
Window
Help
Pole-Zero Map
Imaginary Axis (seconds^-1)
Real Axis (seconds^-1)
×10^5
8
6
4
2
0
-2
-4
-6
-8
-10
5:44 PM
3/21/2020

1.c.)


HOME
PLOTS
APPS
Search Documentation
Log In
New Script
New Live Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Favorites
Analyze Code
Run and Time
Clear Commands
Simulink
Layout
Preferences
Set Path
Add-Ons
Help
Community
Request Support
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C: ▸ Users ▸ oster ▸ Documents ▸ MATLAB
Current Folder
Name
diary
Command Window
New to MATLAB? See resources for Getting Started.
>> T=A/(1+LG)
T =
6.667e05 s^2 + 6.667e11 s
s^3 + 1e06 s^2 + 6.667e11 s
Continuous-time transfer function.
>> bode(T)
Details
Workspace
Name
Value
A
1x1 tf
Af
1x1 tf
B
1x1 tf
LG
1x1 tf
s
1x1 tf
T
1x1 tf
Figure 1
File Edit View Insert Tools Desktop Window Help
Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/s)
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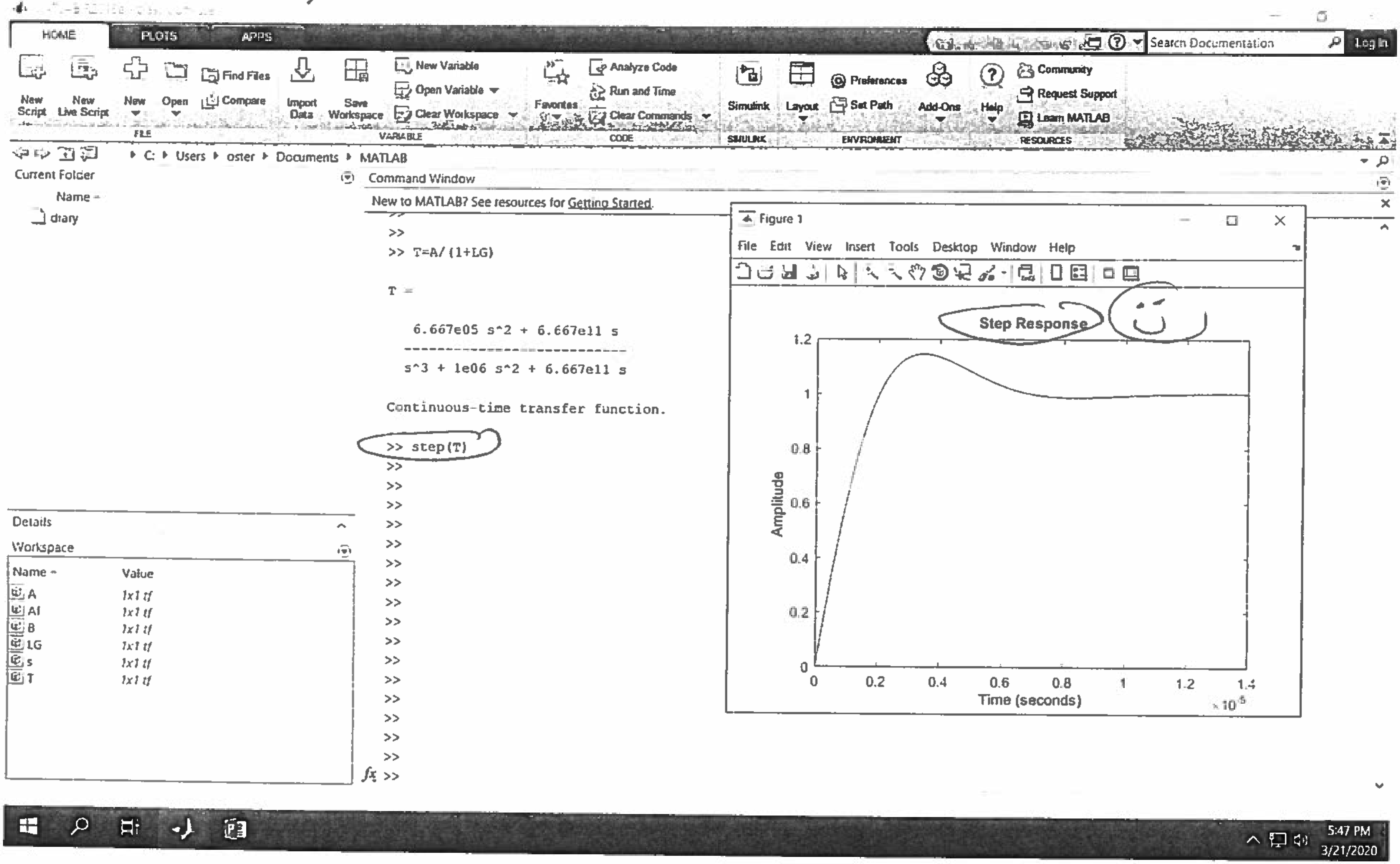
1.d.)



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New Script
New Live Script
New
Open
Find Files
Compare
FILE
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
VARIABLE
Favorites
Analyze Code
Run and Time
Clear Commands
CODE
Simulink
SIMULINK
Layout
Preferences
Set Path
ENVIRONMENT
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Learn MATLAB
RESOURCES
C: ▸ Users ▸ oster ▸ Documents ▸ MATLAB
Current Folder
Name
diary
Command Window
New to MATLAB? See resources for Getting Started.
>>
>> T=A/(1+LG)
T =
6.667e05 s^2 + 6.667e11 s
----
s^3 + 1e06 s^2 + 6.667e11 s
Continuous-time transfer function.
>> step(T)
Details
Workspace
Name
Value
A
1x1 tf
Al
1x1 tf
B
1x1 tf
LG
1x1 tf
s
1x1 tf
T
1x1 tf
Figure 1
File
Edit
View
Insert
Tools
Desktop
Window
Help
Step Response
Amplitude
Time (seconds)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
$\times 10^{-5}$
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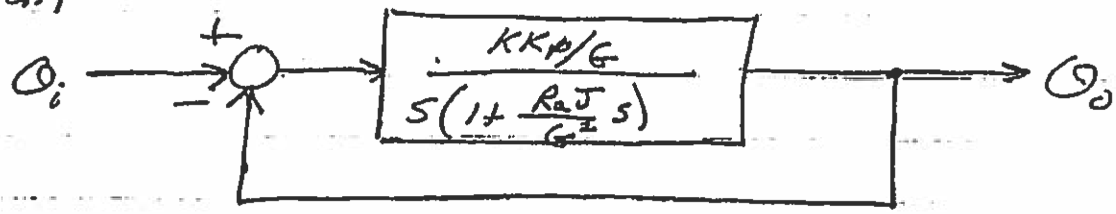
3/21/2020

(2)

a.)



$$\boxed{A_f(s) = \frac{\Theta_o}{\Theta_i}(s) = \frac{A}{1+A\beta} = \frac{1}{\frac{R_aJ}{GKK_p}s^2 + \frac{G}{KK_p}s + 1} = \frac{1}{.04s^2 + .2s + 1}}$$

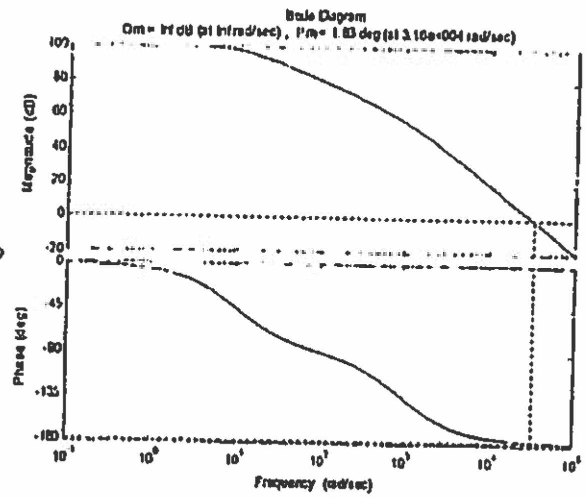
b.) See Next page

c.) See Next Page

d.) $\boxed{LG(s) = A(s)\beta(s) = \frac{KK_pG}{s(1+\frac{R_aJ}{G^2}s)} = \frac{5}{s(1+.2s)}}$

See Next page

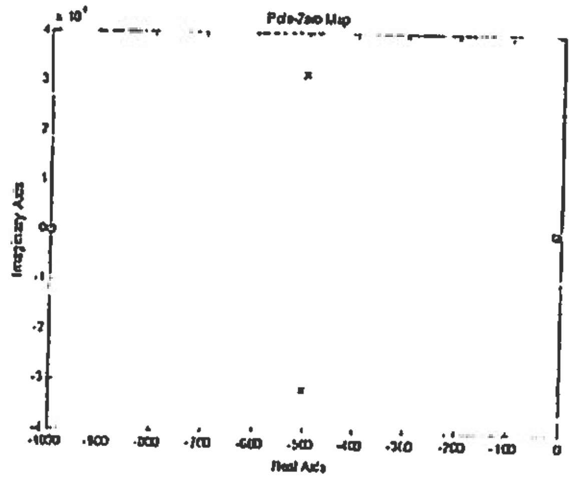
2a. & 2.b. ⇒ $\angle G(s)$



$\omega_1 = 3.16 \times 10^4$ rad/sec

$PM = 1.83°$

2.c. ⇒ (PZ diagram)

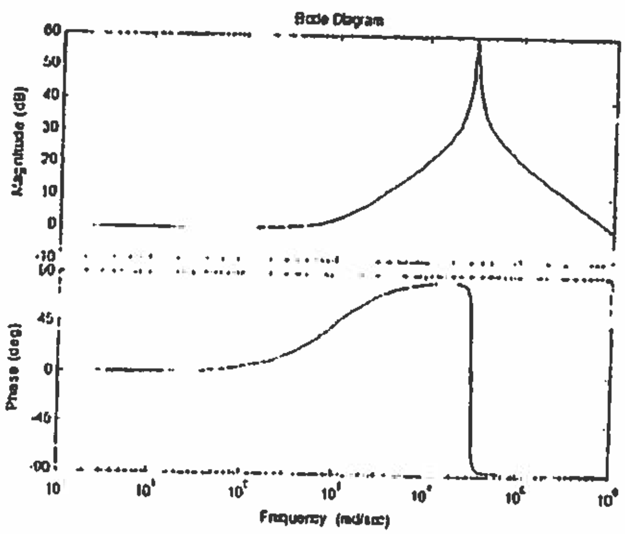


Zero: $s = -1000$

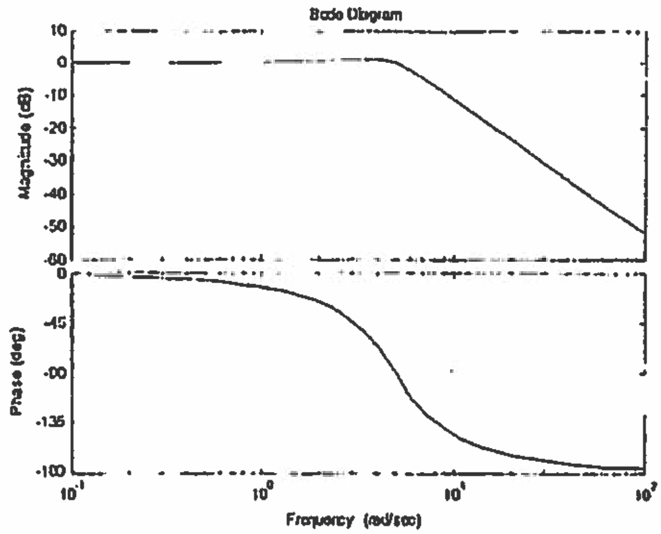
Poles:

$s = -505 \pm j3.16 \times 10^4$

2.c. ⇒ ($A_f(s)$ Bode Plots)

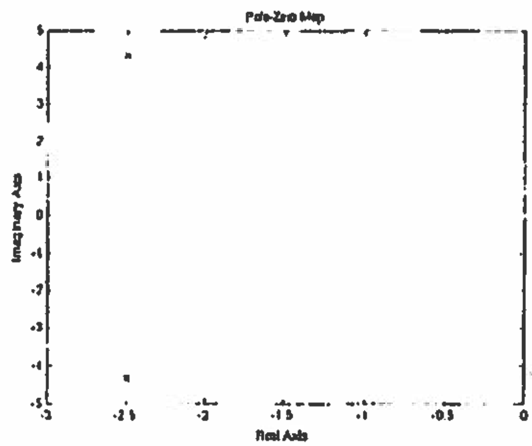


2b.) ⇒ ($A_s(s)$ Bode plots)



$\omega_n = 5$ rad/sec

2c.) ⇒ (PZ Diagram)



Yes, stable

"slightly" under-damped

Poles: $s = -2.5 \pm j4.33$

2.d.) ⇒ ($LG(s)$, GM & PM)