



LEVEL 5 ASSESSMENT SPECIFICATION

Student name:	Harry Own	Student ID number:	
Programme:	HND/HNC Electrical/Electronic Engineering, HNC Instrumentation Engineering & HNC Power System Engineering		
Module:	Electrical Principles, Methods and Simulation		
Module code:	PSDE5009	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Jason Pointer	Internal Verifier:	Steve Roberts
Assignment Title:	Control Systems	Word count (or equivalent):	2000
Submission deadline:	16/05/19	Return date of provisional marks & written feedback:	
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

1. Analyse and evaluate electrical circuits, electronic systems and **control systems**.
2. Simulate standard electrical circuits, electronic systems and **control systems**.

STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	0	0
2. Knowledge and Understanding Skills	30	20.2
Achieved 65% for Task 1. Achieved 80% for Task 2. Achieved 52% for Task 3. Achieved 75% for Task 4. Achieved 65% for Task 5. Knowledge is reasonably extensive and accurate in most parts. Show a very good understanding of most concepts and principles covered by this assignment but not all of the elements were covered for some of the task.		
3. Cognitive and Intellectual Skills	10	3
Largely descriptive work in the analysis of the test results.		
4. Practical Application Skills	50	34.7
Achieved 68% for Task 1. Achieved 78% for Task 2. Achieved 48% for Task 3. Achieved 78% for Task 4. Achieved 75% for Task 5. A very good application of established methods in the use of Matlab, Multisim and Simulink but in places not all of the required work was produced.		
5. Transferable Skills for Life and Professional Practice	10	5
Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed.		

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)

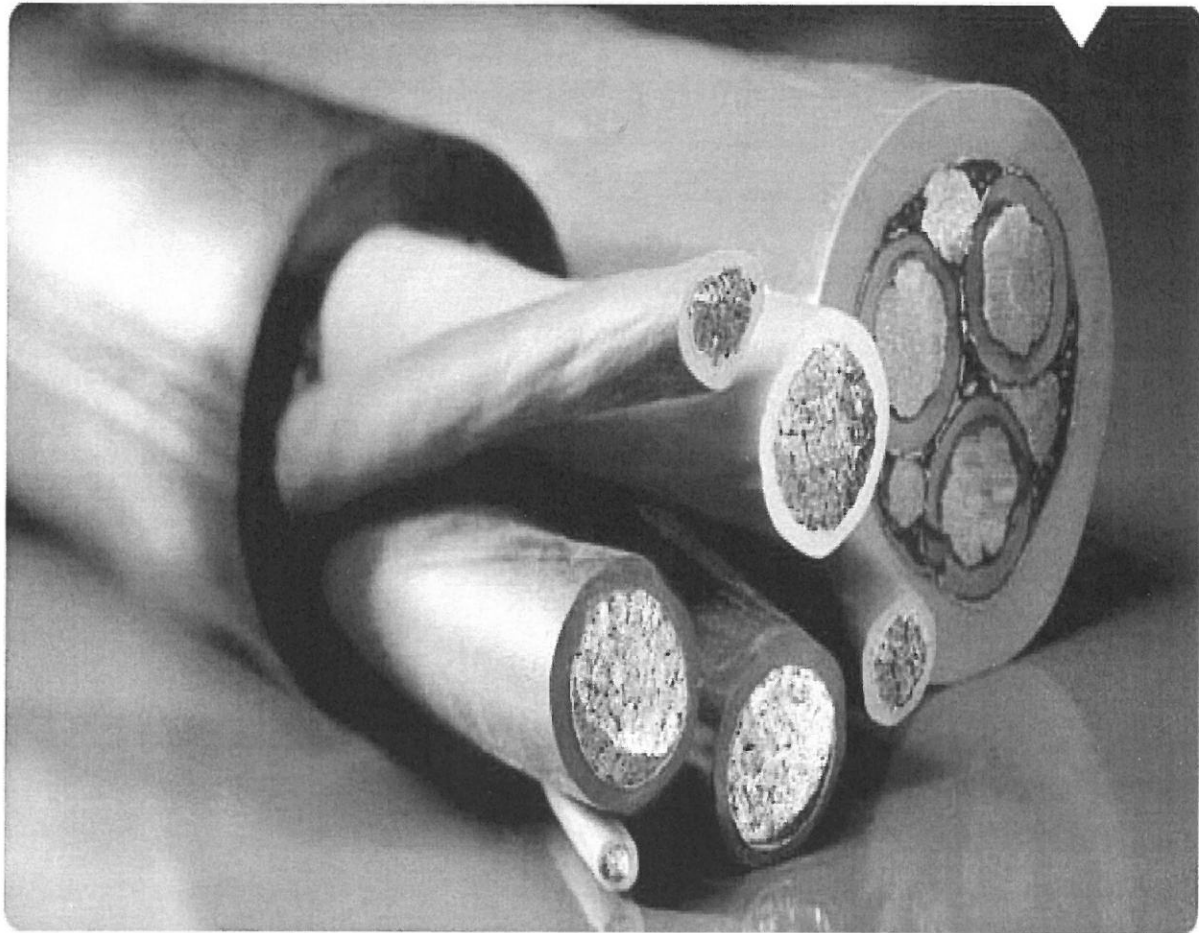
Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

63%

Electrical Principles, Methods and Simulation



By Harry Owen

REFERENCES

Title picture –

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Harry Owen

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Introduction

In this assignment I will be focusing on analysing and evaluating electrical circuits, electronic systems and control systems. This is going to include RC circuits, DC (Direct Current) motors and circuit and Position Control Servo circuits. I will be using simulink as well as MatLab to design and plot a Nyquist diagram. I will also be looking at simulating standard electrical circuits, electronic systems and control systems to gather results which can be analysed and evaluated.

Task 1 – RC Circuit First Order System

Figure 1 shows a RC circuit that can be analysis using time and frequency response.

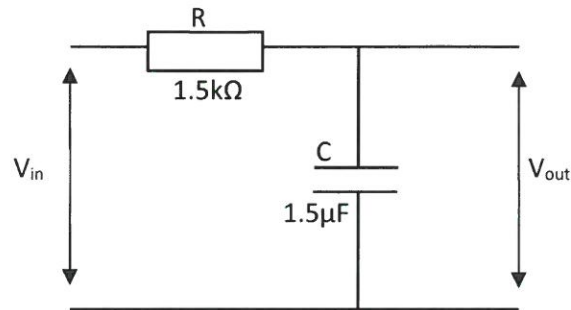
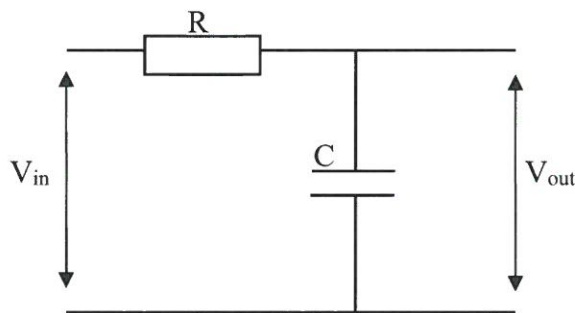


Figure 1

- a. Determine the transfer function for the circuit and using this produce the time response equation.

$$R = 1.5K\Omega \quad C = 1.5\mu F$$



Voltage in R: $Ri(t)$

Voltage in C: $\frac{1}{C} \int i(t) dt$

Using Kirchhoff voltage law -

$$Ri(t) + \frac{1}{C} \int i(t) dt = V_{in}(t)$$

First derivative on both sides above gives

$$R \frac{di(t)}{dt} + \frac{1}{C} i(t) = \frac{dV_{in}(t)}{dt}$$

Using Laplace transform

$$sRI(s) + \frac{I(s)}{C} = sV_{in}(s)$$

$$I(s) \left[sR + \frac{1}{C} \right] = sV_{in}(s)$$

$$I(s) \left[R + \frac{1}{Cs} \right] = V_{in}(s)$$

$$V_{in}(s) = I(s) \left[R + \frac{1}{Cs} \right] \quad \text{eq (1)}$$

Also

$$V_{out} = \frac{1}{C} \int i(t) dt$$

$$\frac{dV_{out}}{dt} = \frac{i(t)}{C}$$

Using Laplace transform

$$sV_{out}(s) = \frac{I(s)}{C}$$

$$I(s) = sV_{out}(s) \times C$$

Sub into equation (1)

$$V_{in}(s) = sV_{out}(s) \times C \left[R + \frac{1}{Cs} \right]$$

$$\frac{V_{in}(s)}{V_{out}(s)} = sC \left[R + \frac{1}{Cs} \right] = CRs + 1$$

So

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{1}{CRs + 1}$$

Divide top and bottom by **CR**

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{1/CR}{s + 1/CR}$$

Take inverse Laplace transforms:

$$\frac{v_{out}(t)}{v_{in}(t)} = \frac{1}{CR} \times e^{-\frac{t}{CR}}$$

$$v_{out}(t) = v_{in}(t) \times \frac{1}{CR} e^{-\frac{t}{CR}}$$

B) Use Matlab to produce the time response plot when 20V dc voltage is applied at Vin and also to calculate the time constant, delay time and rise time. Confirm the plot by using Simulink.

```
%Harry Owen Electronic Principles Assignment 2  
%Task 1 Matlab for first order response of a RC circuit.
```

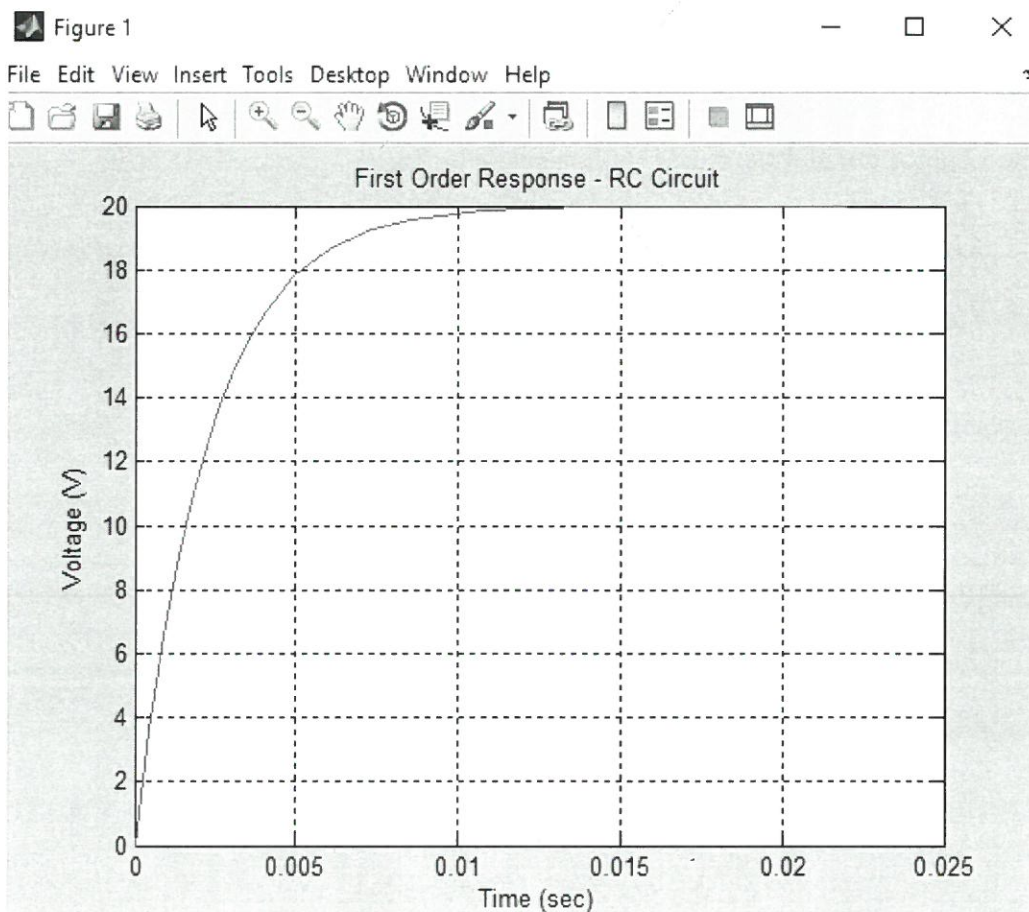
```
% Setting the value for a resistor, capacitor and voltage  
R = 1.5*10^3; C = 1.5*10^-6; V = 20;
```

```
Tc=R*C;      % Calculate time constant  
t=0;         % Set initial conditions  
Vout=0;
```

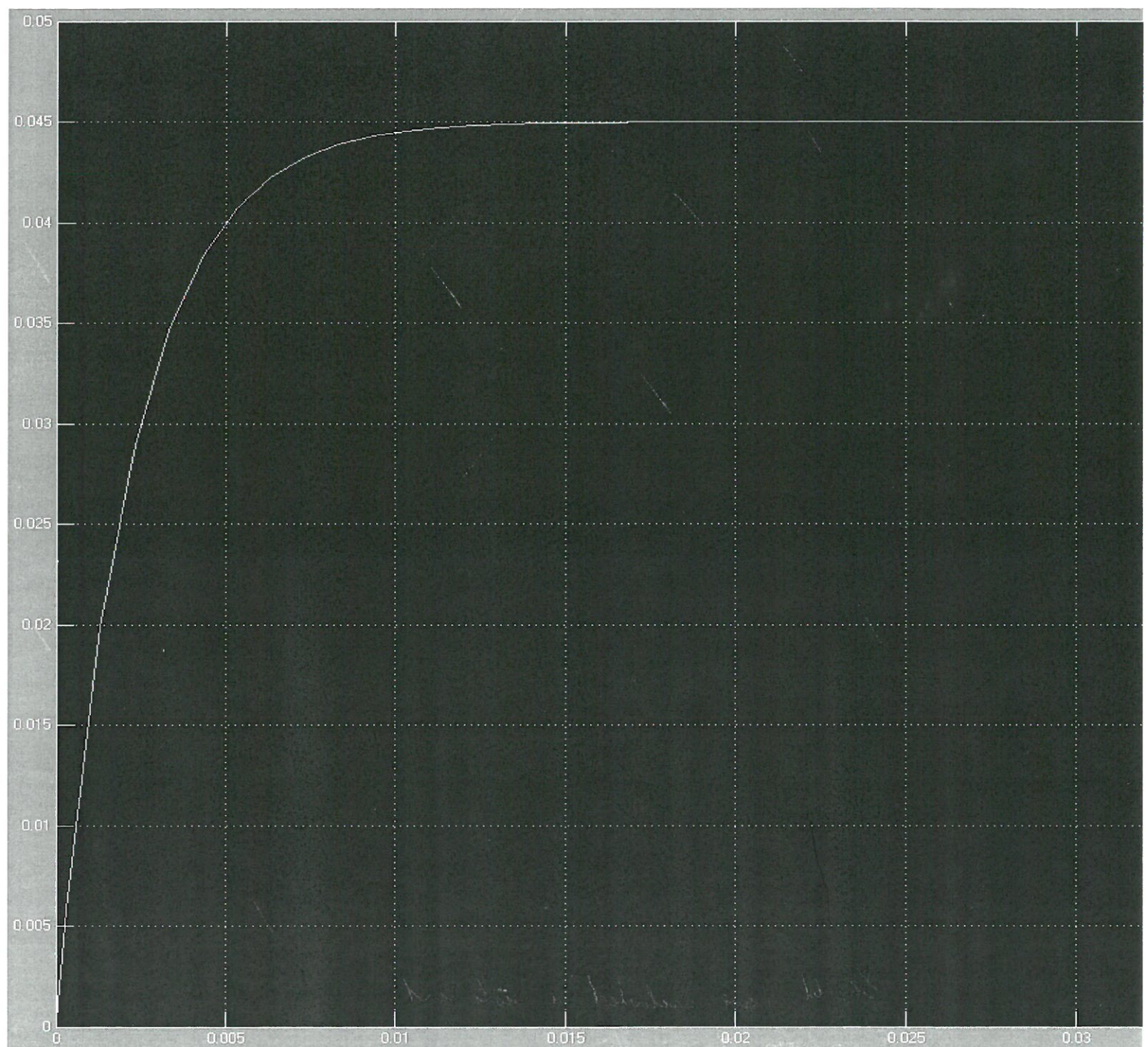
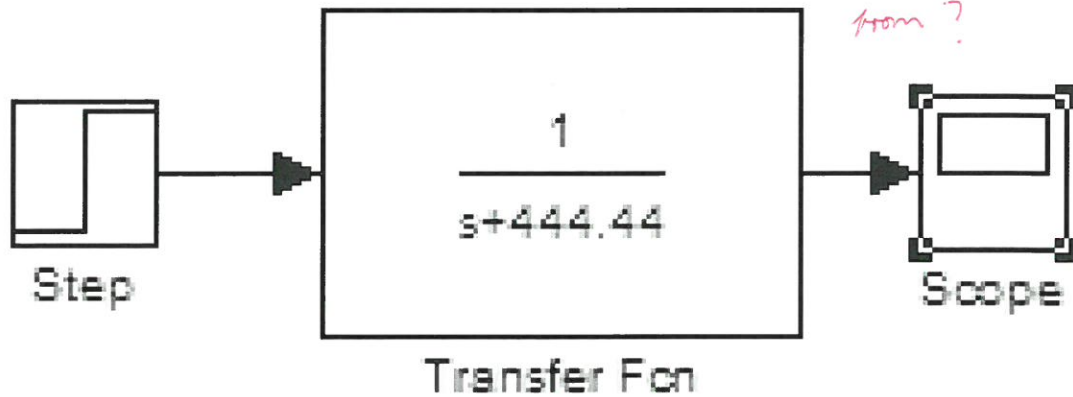
```
% Determine the output voltage for value of time, t.  
for H=1:50  
    t(H)=(H-1)*Tc/5;  
    Vout(H)=V*(1-exp(-t(H)/Tc));  
end;
```

```
% Display the Vout against time  
plot(t,Vout,'r-');  
title('First Order Response - RC Circuit')  
xlabel('Time (sec)')  
ylabel('Voltage (V)')  
grid
```

*Have not determined
delay and rise time.*



Proving using Simulink.



By Harry Owen

How did the results compare?

C) If a sine wave is now applied to the input the frequency response of the circuit can be determined. Use a 1V peak to peak sine wave and Matlab to produce the frequency response for the magnitude also determine the cut-off frequency.

```
% Harry Owen Matlab Program to find Time Constant:

% Frequency response for a RC circuit with a 1 Volt sine wave

% Set Component Values
R = 1500; C = 1.5*10^-6;

f=0; % Set initial conditions

% The Time constant
Tc=R*C;

fx=0:0.5:2000;
z=length(fx);

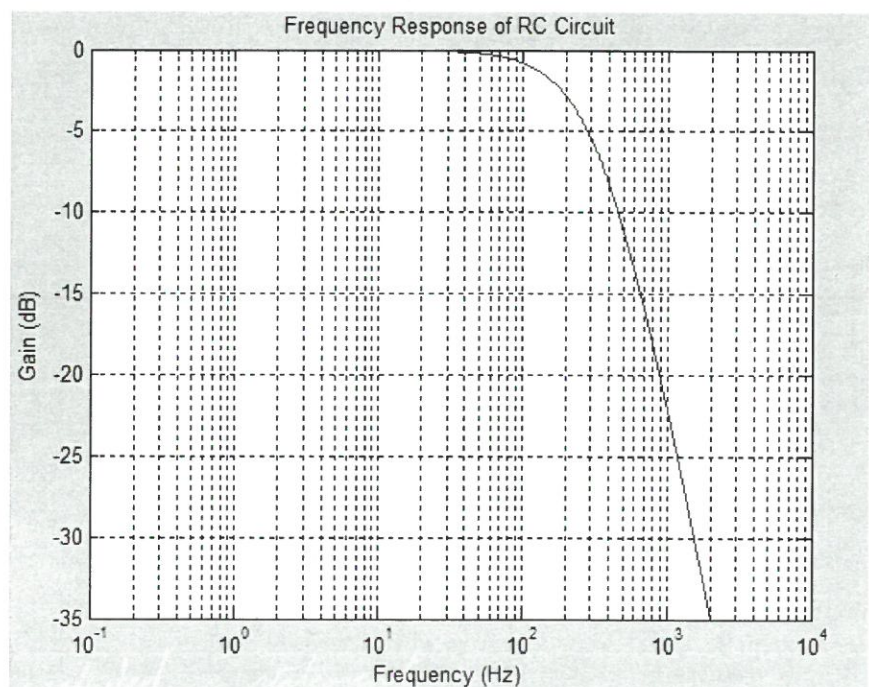
% For loop
for x=1:z
    f=f+0.1;

    % Angular velocity
    w(x)=2*pi*f;

    % Time response
    G(x)=20*log(1/(sqrt(1+w(x)^2*Tc^2)));
end

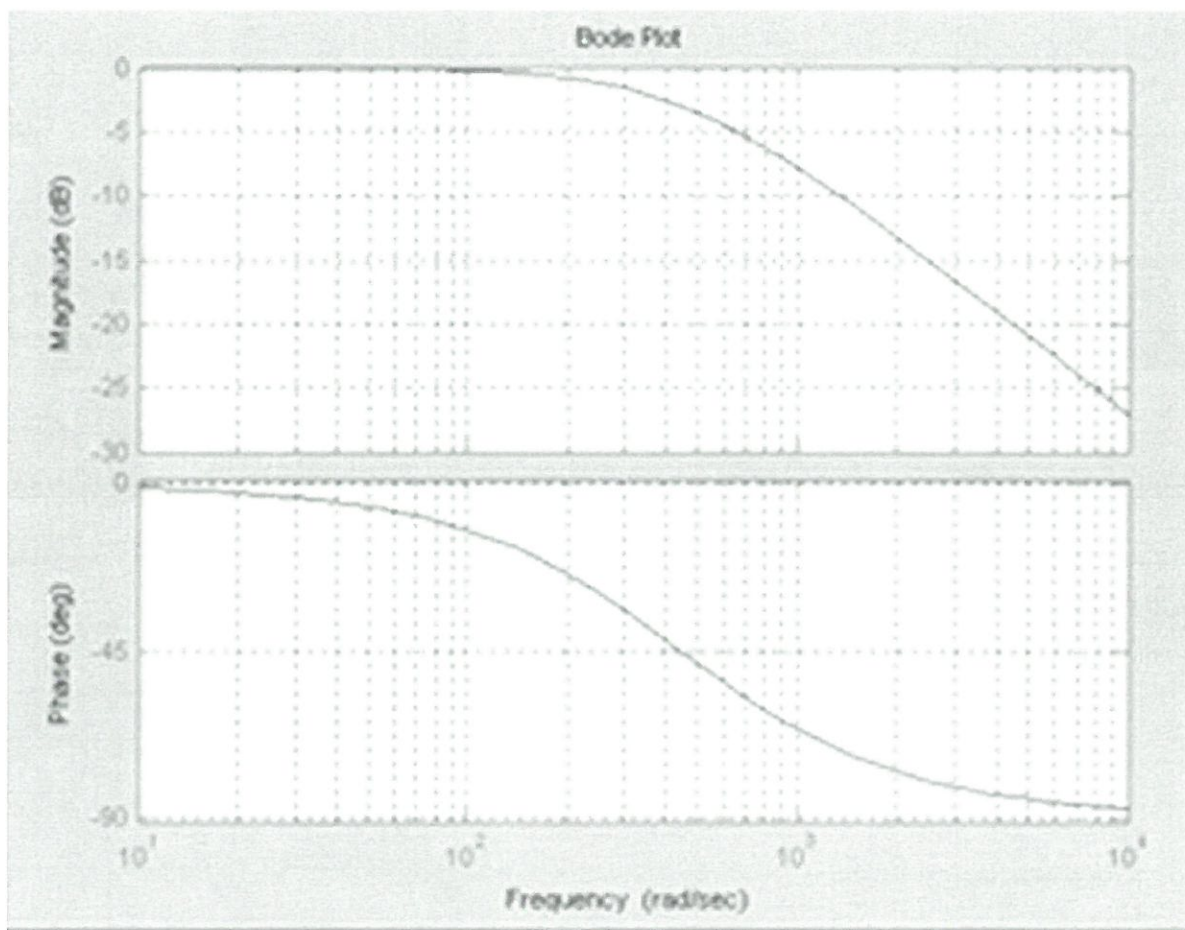
% The frequency Response
semilogx(fx,G)
xlabel('Frequency (Hz)')
ylabel('Gain (dB)')
title('Frequency Response of RC Circuit')
grid
```

The cut off frequency is 200Hz. This is the point where the wave drops off 3dB.

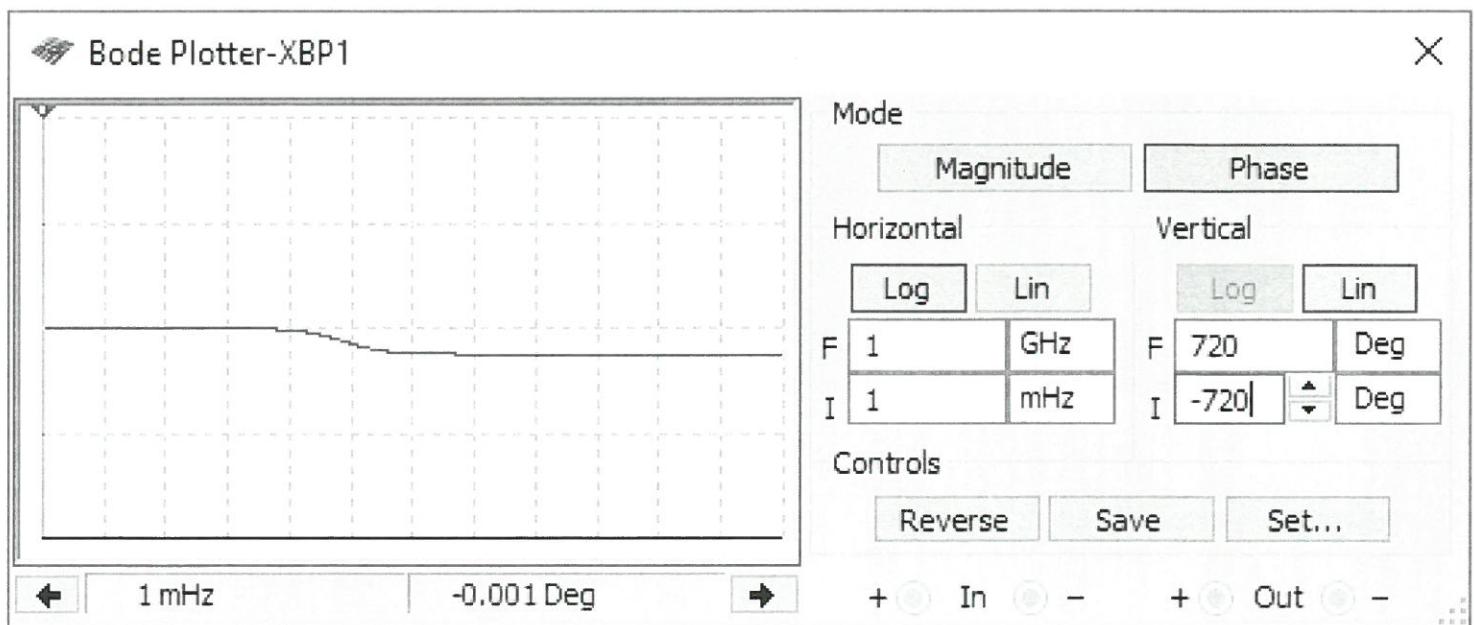
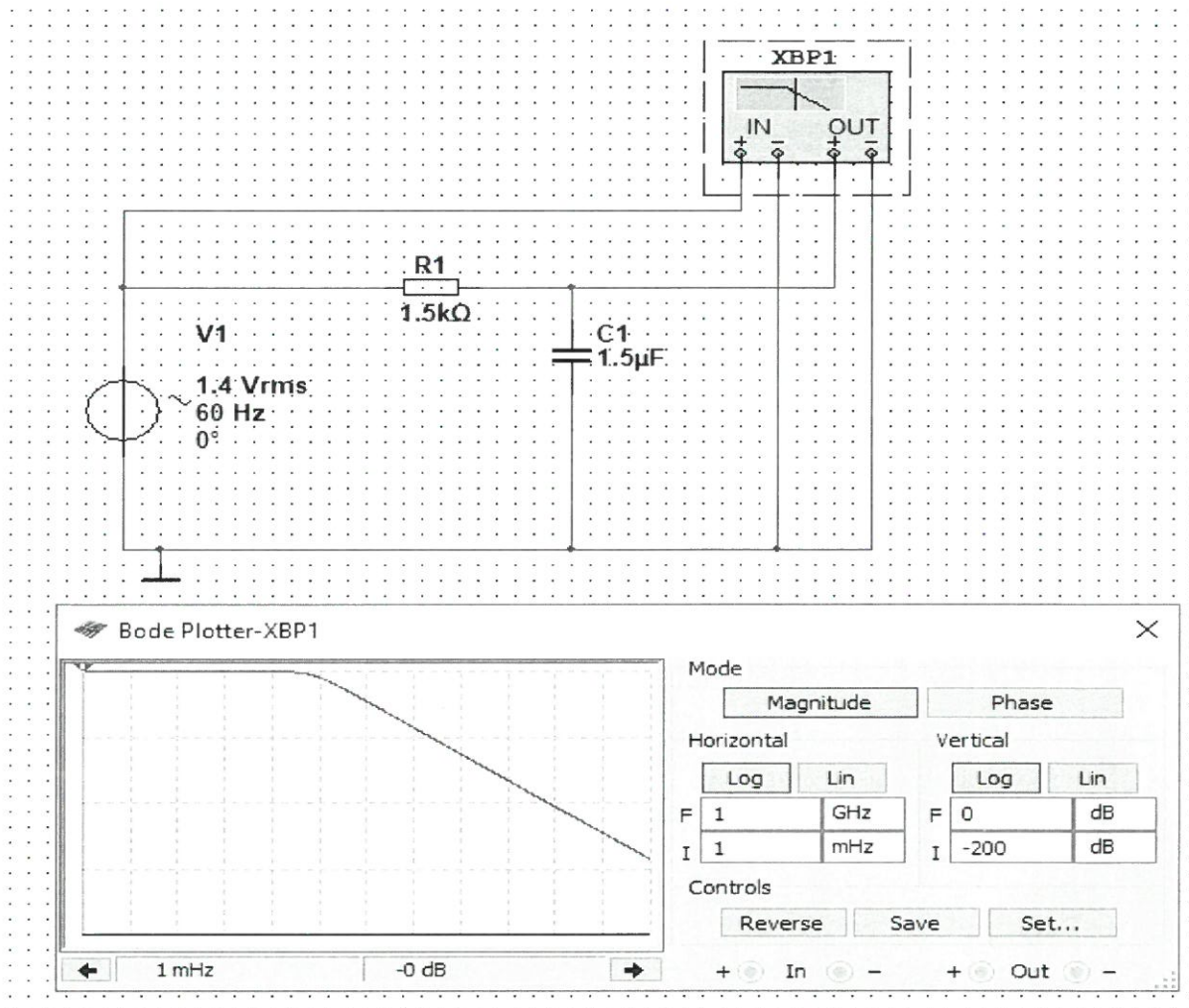


D) The frequency response can also be represented using a Bode plot which will include magnitude and phase plots. Use Matlab to produce a Bode plot and confirm the results using Multisim.

```
% Harry Owen  
% Creating the frequency response using Bode Plot  
  
% Create Transfer Function  
Graph=tf([1],[0.00225,1]);  
  
% Bode Plot  
bode(Graph)  
grid  
title('Bode Plot')
```



A bit out of focus.



Should have included a statement to confirm the results.

Task 2 –

- 1- Using Matlab write an m-file to find the motor constant K_M and to plot the speed-torque relationship. The motor parameters are: $R_a = 1.4\Omega$; $V_a = 12V$ and the stall torque $T_s = 0.21453Nm$.

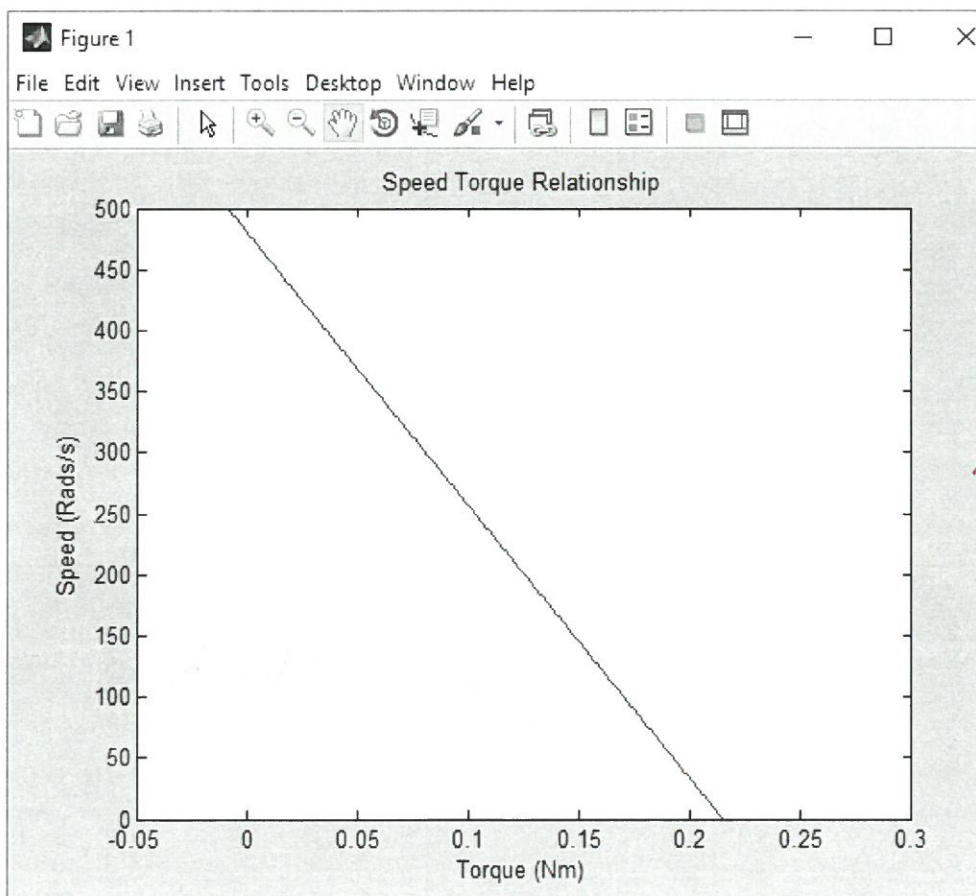
```
% Task 2 Harry Owen
Ra=1.4; Va=12; Ts=0.21453;    % Motor parameters

km=(Ts*Ra)/Va;                % Calculation of Motor constant

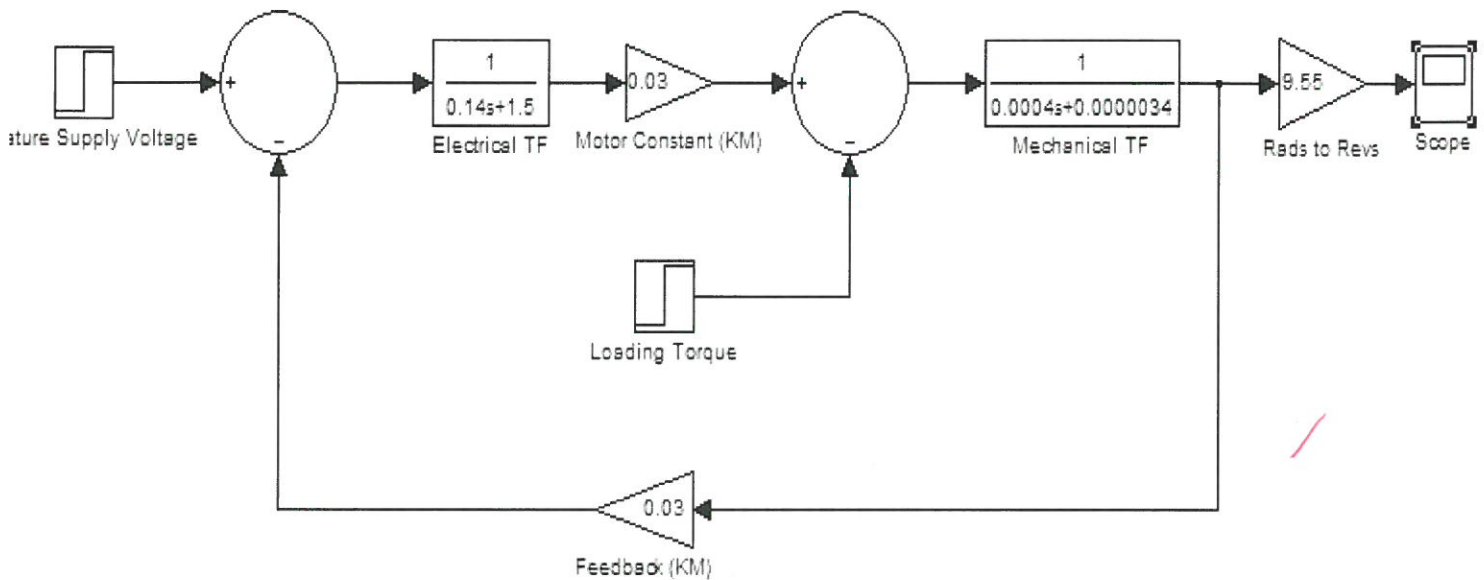
% Speed Range
W=0:2:500;
T=km*(Va-km*W)/Ra;

% Display the results
disp('The Motor Constant, km')
disp(km)
plot(T,W,'b-')
xlabel('Torque (Nm)')
ylabel('Speed (Rads/s)')
title('Speed Torque Relationship')
```

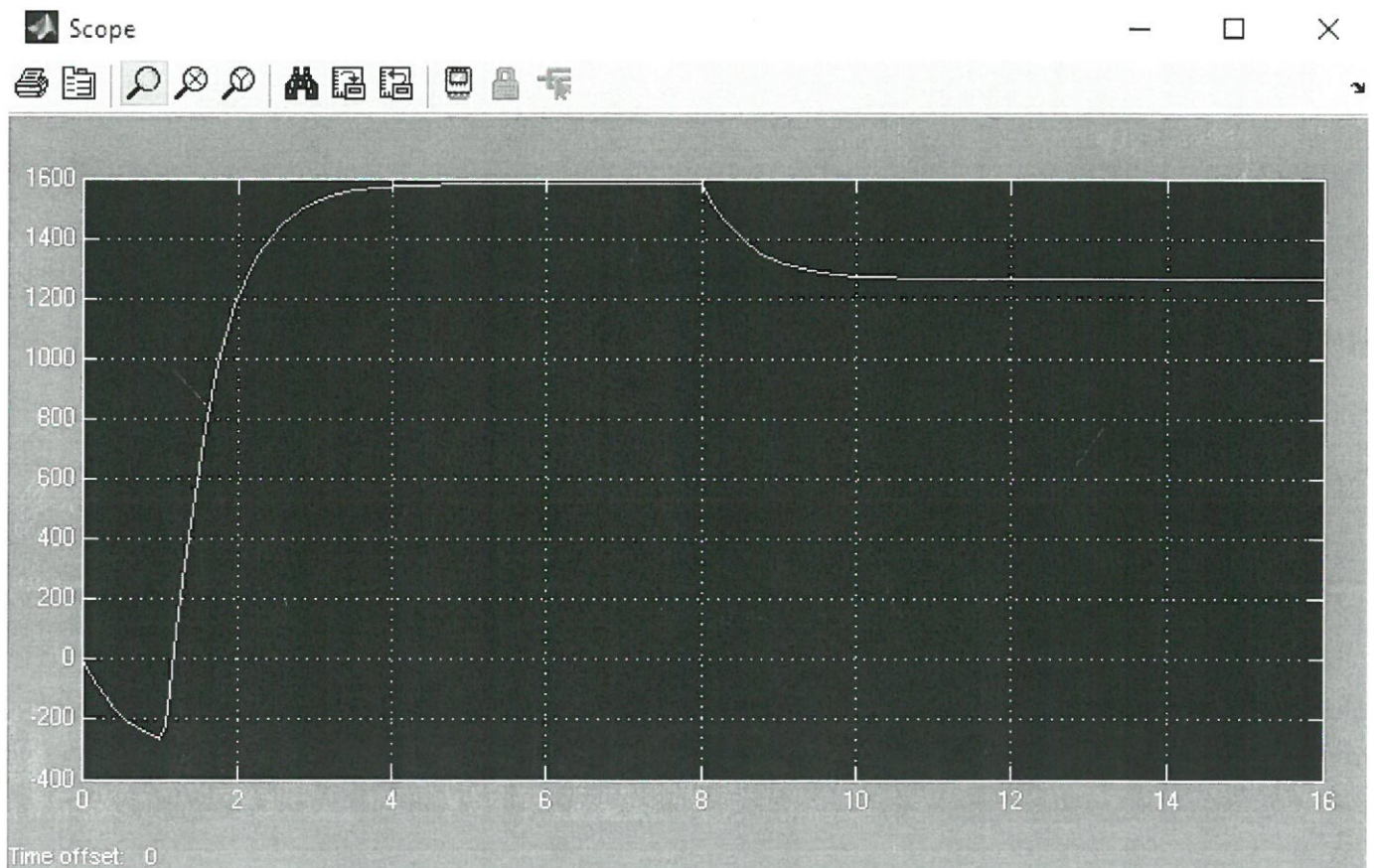
The Motor Constant, $k_m = 0.0250$



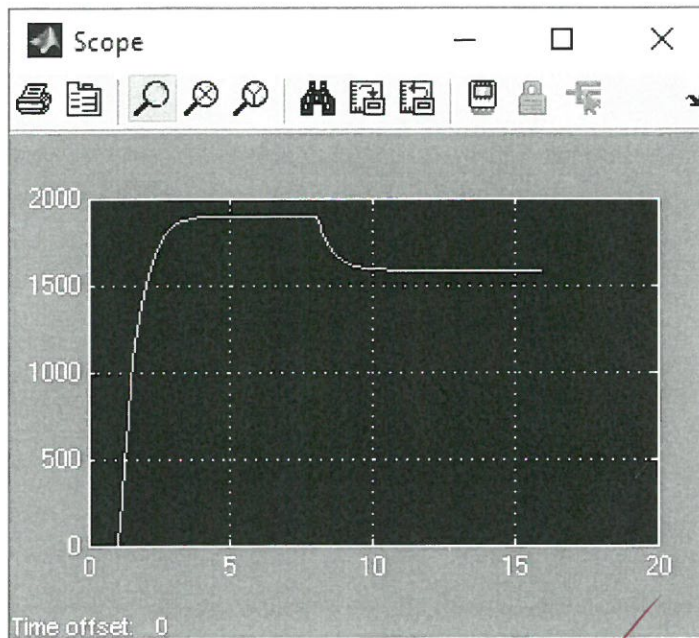
B - Build a Simulink model for the armature-voltage controlled DC motor. The motor parameters are $R_a = 1.5\Omega$, $L_a = 0.14H$, $K_m = 0.03Nm/A$, $J = 0.0004kgm^2$, $b = 3.4 \times 10^{-6}Nm/s/rad$ and $V_a = 6V$.



C - Run the simulation model and plot the speed response (in rpm) for the first 16 seconds when the load of a DC motor changes between 0.02Nm and 0.04Nm with frequency 0.125Hz.

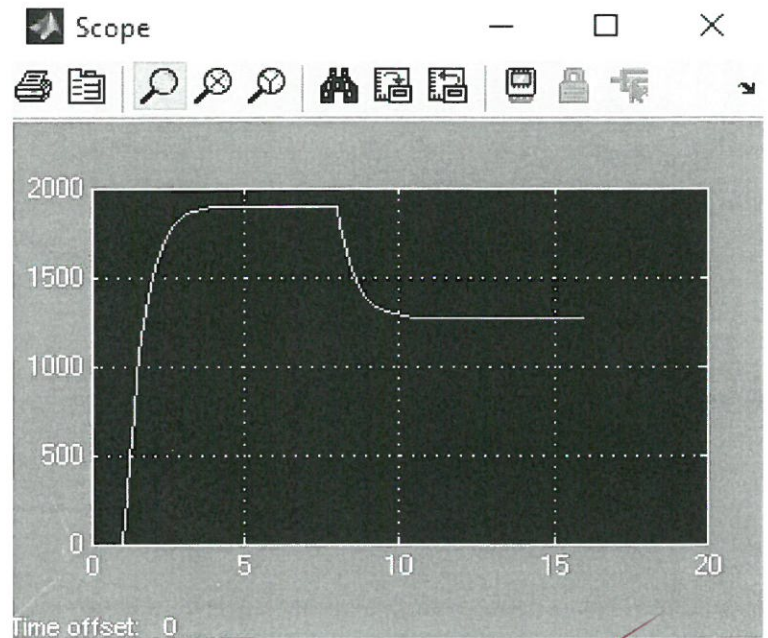


D- Find out the steady state angular speeds (in rpm) at load 0.02Nm and 0.04Nm, respectively.



Settled at 1583 rpm

Units



Settle at 1266 rpm

Task 3 - Position Control Servo

Figure 3 shows the circuit diagram for a Position Control Servo:

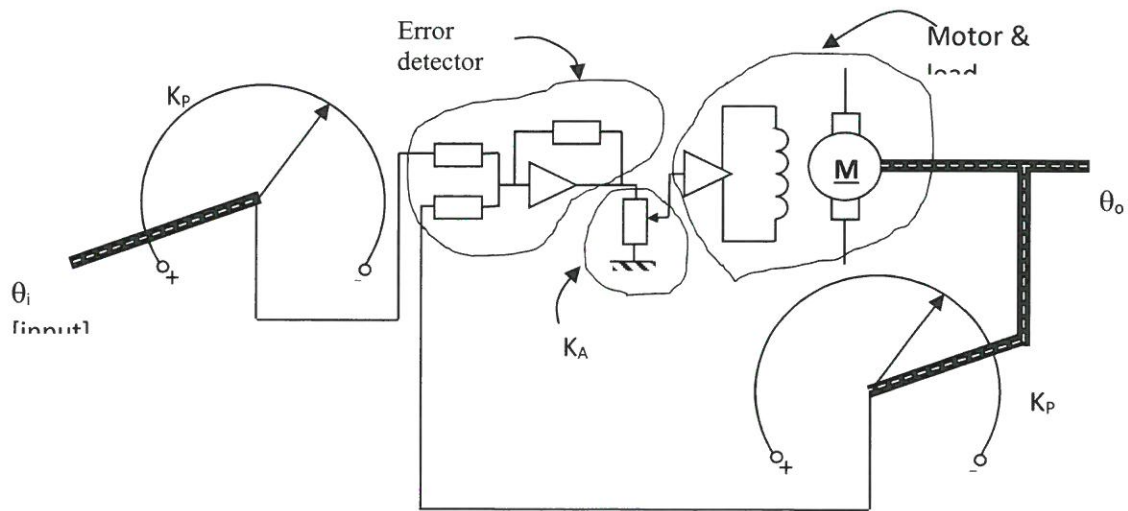
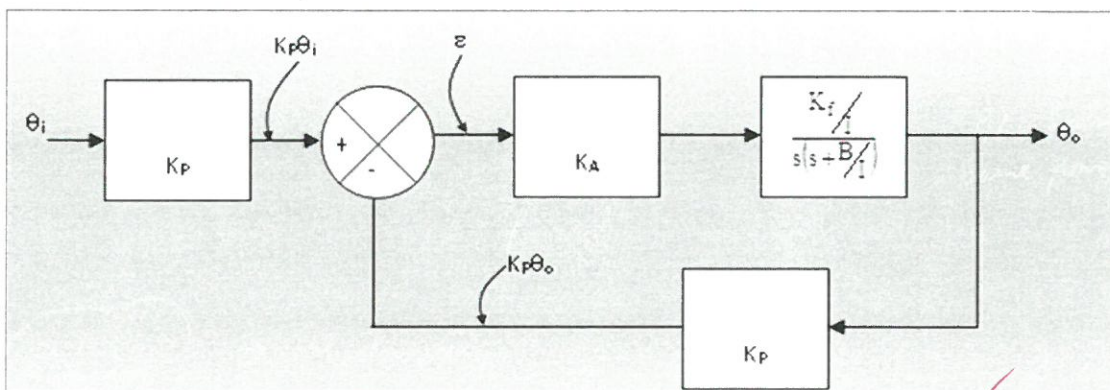


Figure 3

Where the motor & load has the transfer function: $\frac{\theta(s)}{i_f(s)} = \frac{K_f/I}{s(s+B/I)}$ ✓

A) Sketch a block diagram for the system.



B) From your block diagram show that the transfer function for the system is:

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{K_A K_P K_F / I}{s^2 + \frac{sB}{I} + \frac{K_A K_P K_F}{I}}$$

The standard equation for negative feedback system. $\frac{\theta_o}{\theta_i} = \frac{G(s)}{1 + G(s)H(s)}$

$$G(s) = K_A \times \frac{K_F / I}{s(s + B/I)}$$

$$H(s) = K_P$$

The overall Transfer function

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{K_P \times \frac{K_A K_F / I}{s(s + B/I)}}{1 + K_P \times \frac{K_A K_F / I}{s(s + B/I)}}$$

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{\frac{K_P K_A K_F / I}{s^2 + Bs/I}}{1 + \frac{K_P K_A K_F / I}{s^2 + Bs/I}}$$

Multiply by $(s^2 + Bs/I)$

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{\frac{(s^2 + Bs/I) \times K_P K_A K_F / I}{s^2 + Bs/I}}{(s^2 + Bs/I) \times 1 + \frac{(s^2 + Bs/I) \times K_P K_A K_F / I}{s^2 + Bs/I}} = \frac{\frac{K_P K_A K_F}{I}}{s^2 + \frac{Bs}{I} + \frac{K_P K_A K_F}{I}}$$

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{\frac{K_P K_A K_F}{I}}{s^2 + \frac{Bs}{I} + \frac{K_P K_A K_F}{I}}$$

- C) A unit step input is to be applied to the position control servomechanism and the following parameters are applied:

$$K_A = 1.0$$

$$K_P = 5Vr-1$$

$$K_f = 8mAV-1$$

$$I = 2 \times 10^{-4} \text{ Kg m}^2$$

Find the value for B to create a critically damped system and using this value determine the poles of the system. Use Matlab to show that the system is critically damped by obtaining the pole plot and also to show stability.

Finding the value of B

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{\frac{K_P K_A K_F}{I}}{s^2 + \frac{Bs}{I} + \frac{K_P K_A K_F}{I}}$$

$$\frac{\theta_o(s)}{\theta_i(s)} = k_{ss} \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{\frac{5 \times 1 \times 8 \times 10^{-3}}{2 \times 10^{-4}}}{s^2 + \frac{Bs}{2 \times 10^{-4}} + \frac{5 \times 1 \times 8 \times 10^{-3}}{2 \times 10^{-4}}} = \frac{200}{s^2 + 5000Bs + 200}$$

$$\omega_n^2 = 200$$

So Steady state value = $k_{ss} = 1$

$$\text{Natural frequency} = \omega_n = \sqrt{200} = 14.14 \text{ rad/sec}$$

$$2\zeta\omega_n = 5000B$$

for critically damping $\zeta = 1$

$$\text{So } 2 \times 1 \times 14.14 = 5000B$$

$$B = \frac{22.28}{5000} = 5.656 \times 10^{-3} \text{ N/ms}^{-1}$$

To determine the poles for critically damped

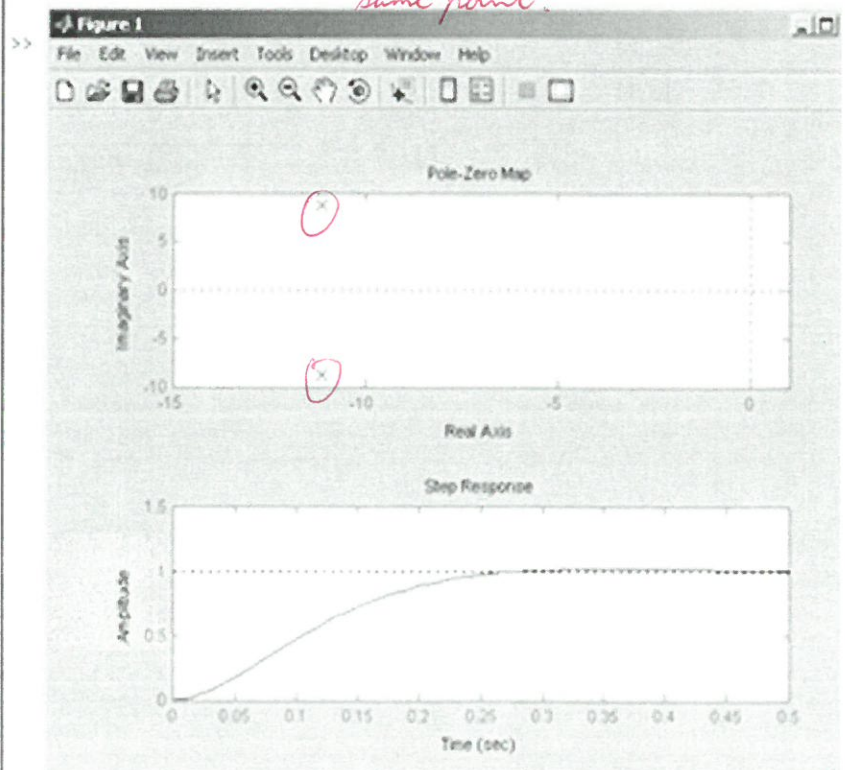
$$(s^2 + 2\omega_n s + \omega_n^2) = 0$$

$$s = -\omega_n, -\omega_n = -14.14$$

ans =

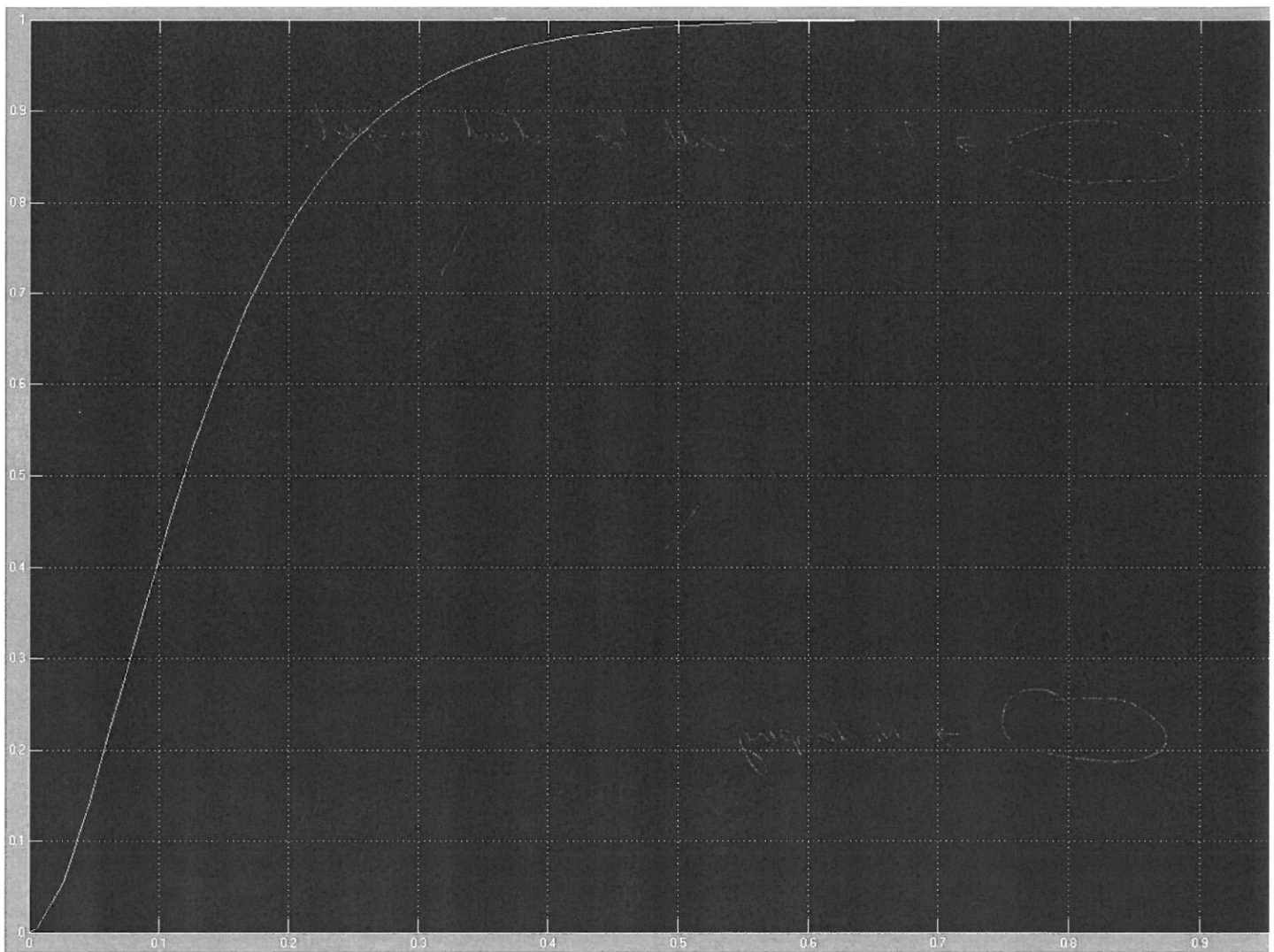
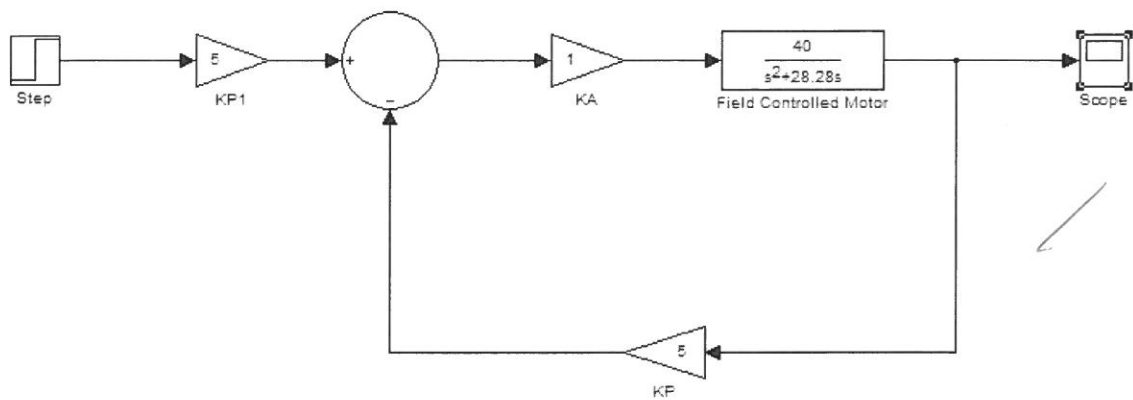
$$\begin{aligned} -11.1400 + 8.71211i \\ -11.1400 - 8.71211i \end{aligned}$$

The poles should be at the same point.



You have not included your Matlab program.

D) Obtain the time response of the system using Matlab and compare its performance by modelling it in Simulink.



E) Modify your Matlab program to allow different values of B to be entered producing the time response and pole plot to check stability. Select suitable values of B for the following conditions:

- No damping
- Under damped
- Over damped

Critically damped = $B = 5.565 \times 10^{-3} = 0.005565$

So $B/I = 5.565 \times 10^{-3} / 2 \times 10^{-4} = 27.825$

No Damping = $B = 0$

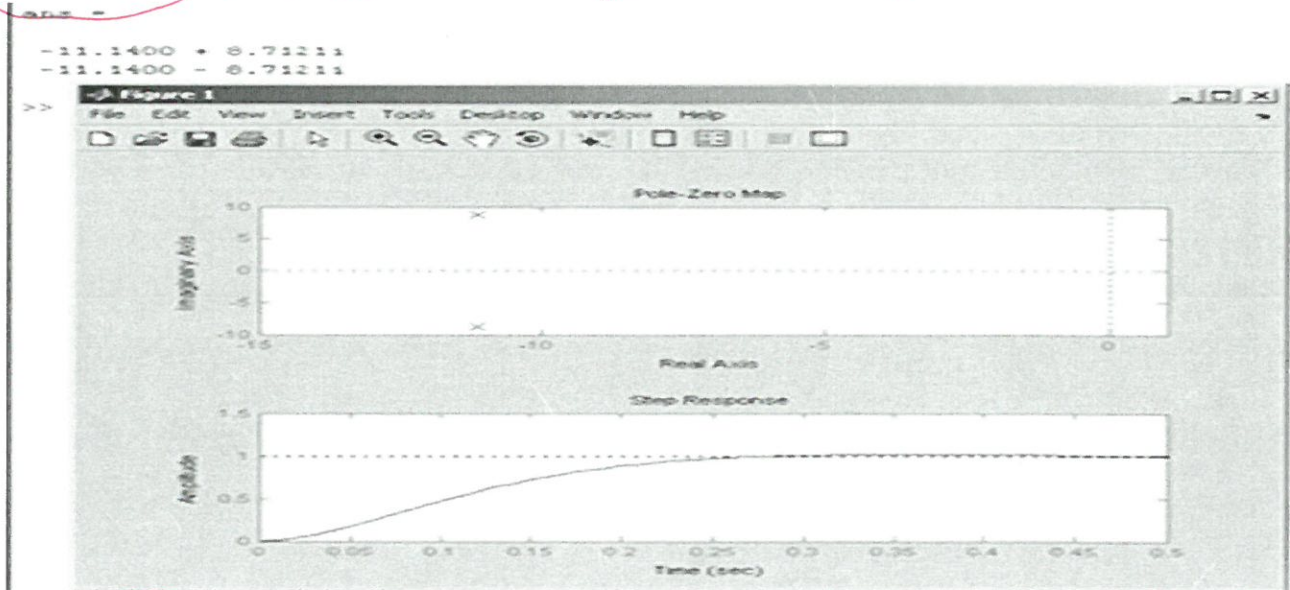
Under Damped (Between 0 and critical value) = $B = 2.5 \times 10^{-3} = 0.0025$

so $B/I = 2.5 \times 10^{-3} / 2 \times 10^{-4} = 12.5$

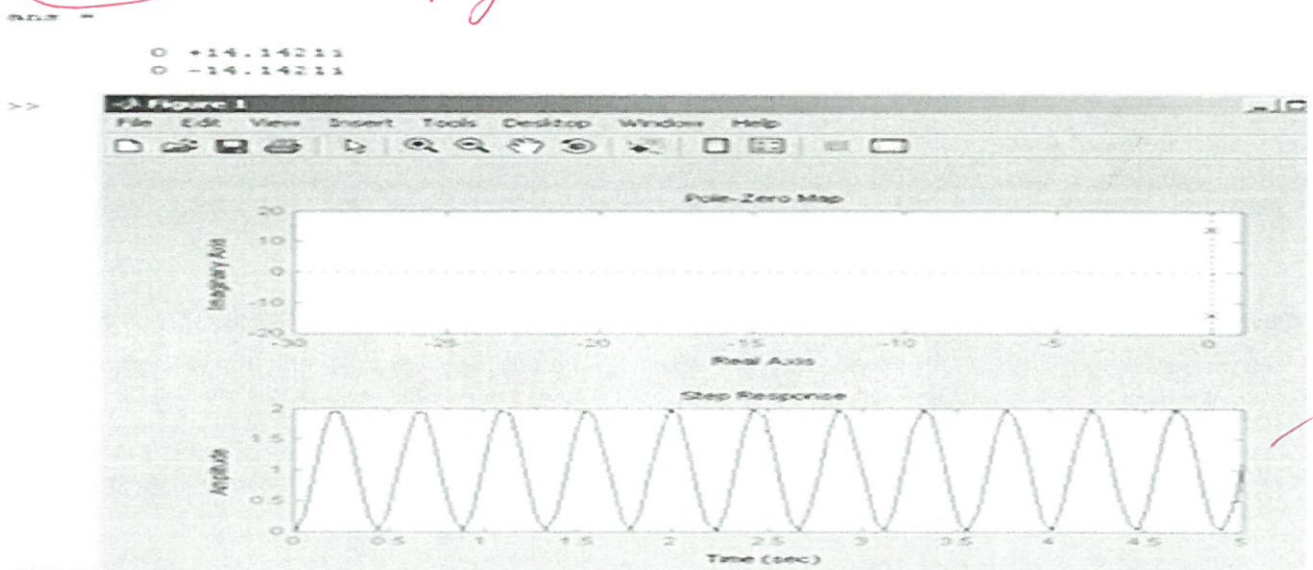
Over Damped (Over the critical value) = $B = 12.5 \times 10^{-3} = 0.0125$

So $B/I = 12.5 \times 10^{-3} / 2 \times 10^{-4} = 62.5$

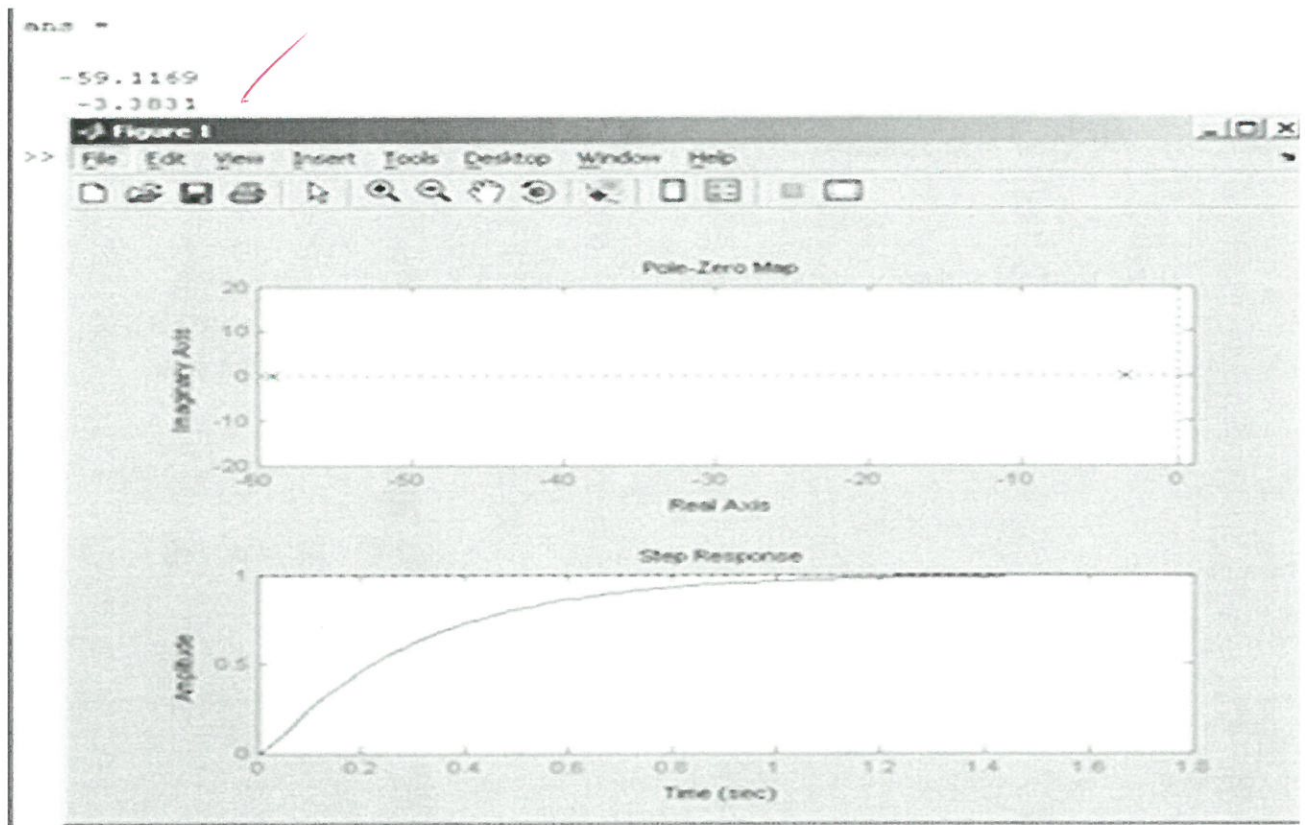
No damping - *→ This is the result for critical damped.*



Under damped - *→ No damping*



Over Damped –



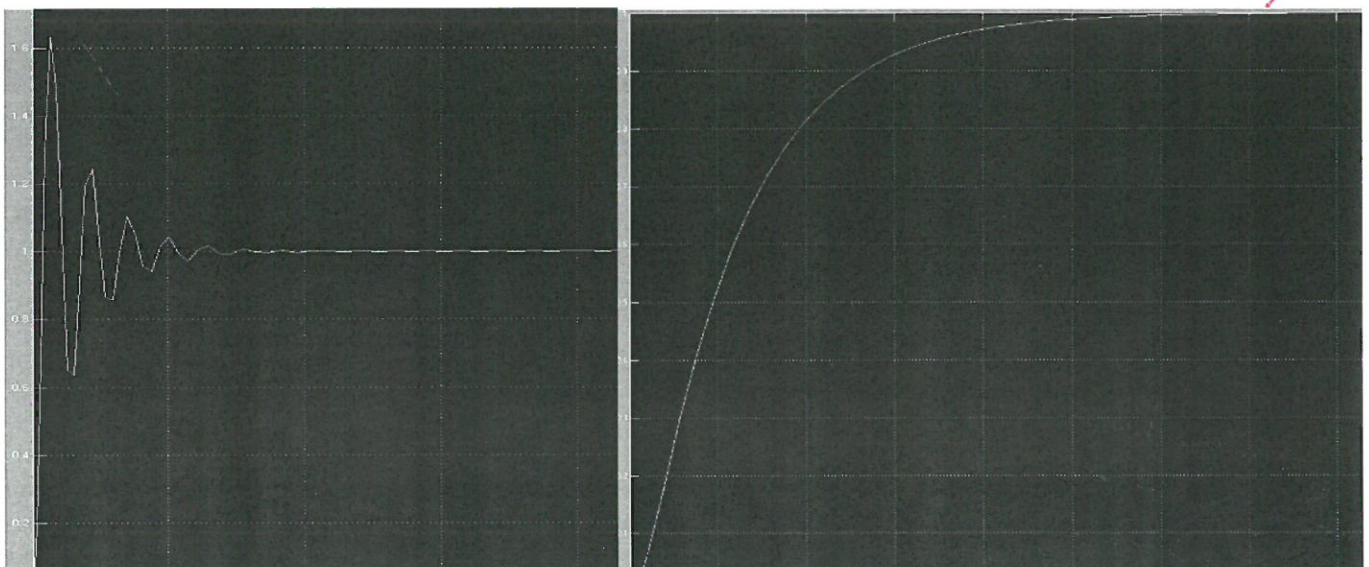
F) - For the under damped condition obtain the following values using Matlab:

- Rise time
- Peak time
- Percentage maximum overshoot
- Settling time

You have not done this.

Also investigate the effect that the proportional controller has upon the performance of the system.

The proportional controller has a lot of effect on the outcome of the circuit. As seen in figures below, a higher proportional figure will allow the user to reach the target mark quicker but with that will be a lot of over shoot and rippling before it settles out. When there is a lower proportional figure, it takes longer to reach the target mark but allows less over shoot and rippling to occur. (Values used below 1st=10 the 2nd=0.1)

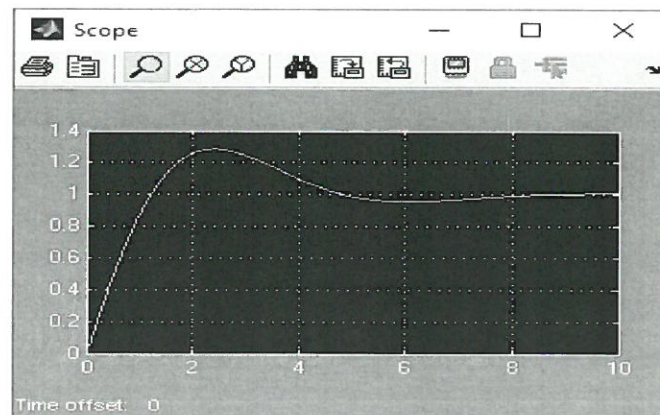
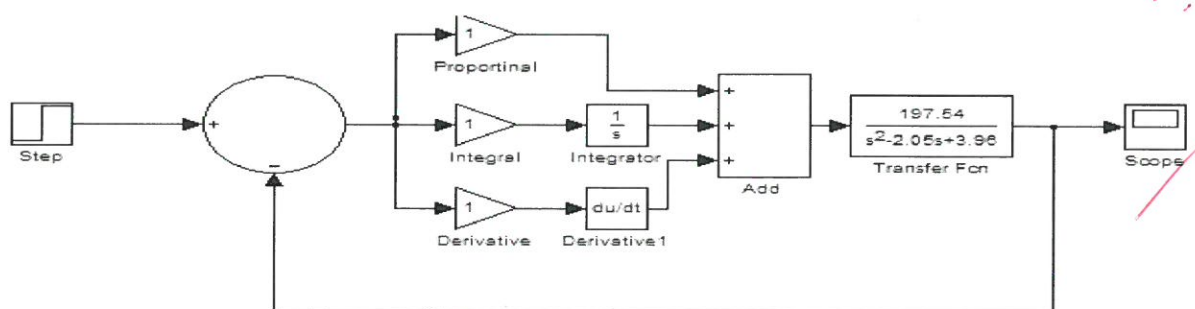
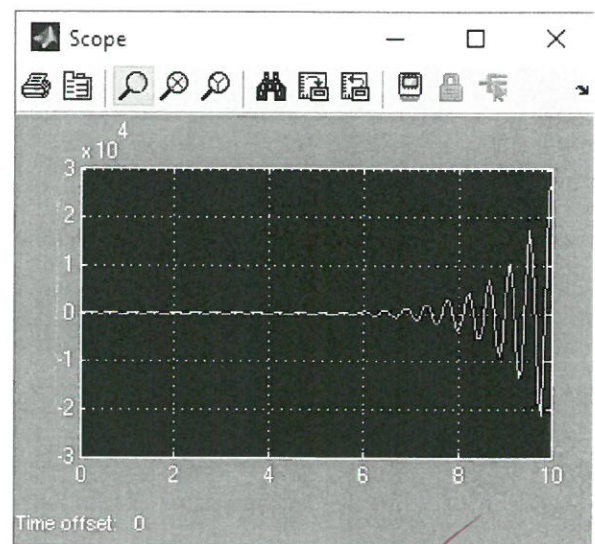
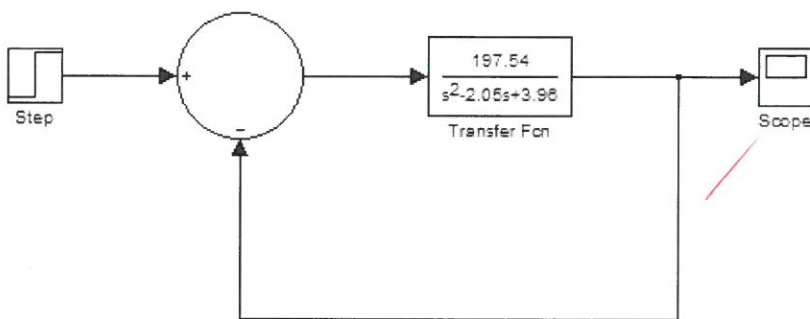


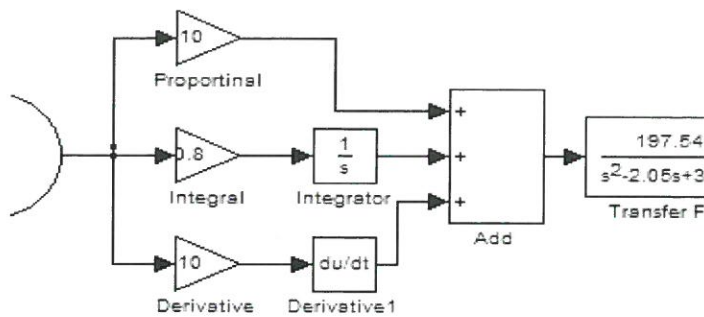
Task 4

An electrical system modelled by

$$G(s) = \frac{197.54}{s^2 - 2.05s + 3.96}$$

Using the trial and error methods, find out parameters K_p , K_i and K_d of the PID controller in Simulink so that the closed-loop system can achieve overshoot $\sigma = 0\%$, rise time t_r less than 0.18 second and zero steady-state error. Plot the unit step response of this closed-loop system for the first 1 second.



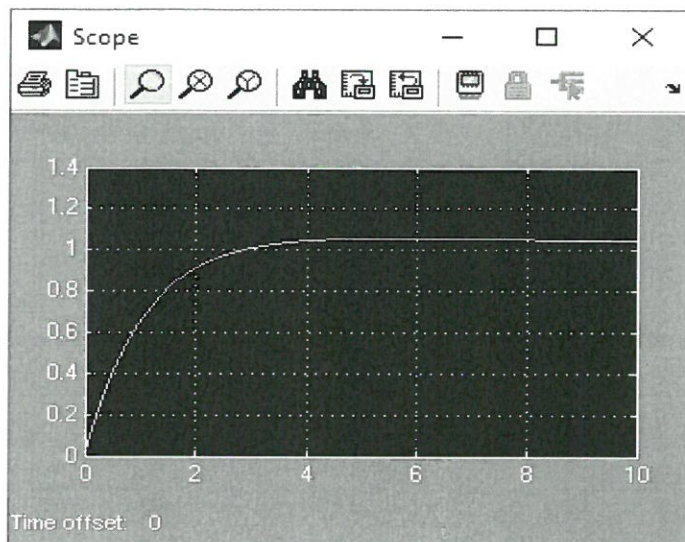


This shows a trail to find the correct values for the PID controller. I firstly increased the proportional and derivative to a higher values to increase start peak and lower the over shoot but this wasn't within the parameters we were given.

Proportional = 10

Integral = 0.8

Derivative = 10

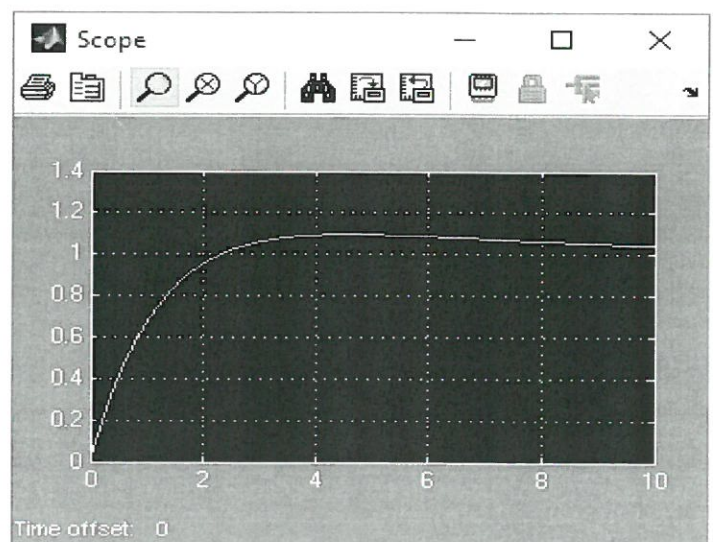
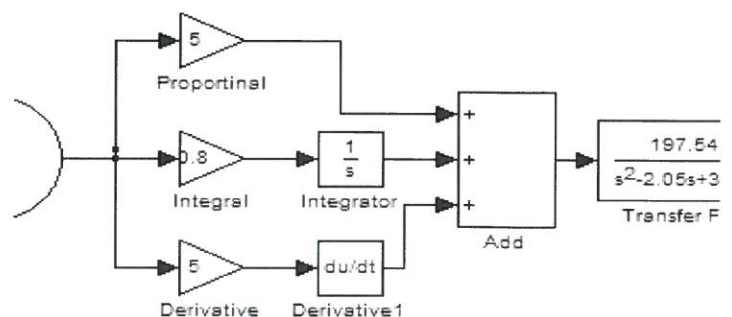


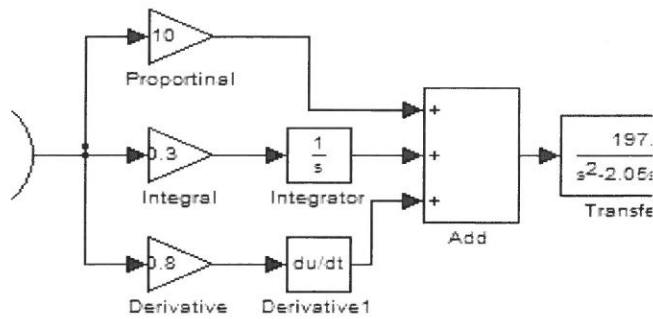
The second attempt was to half those last values and see what the effect would be. It can be seen that the over shoot was worse but it did settle down to the desired final outcome. The rise time was better but still not within the required parameters.

Proportional = 5

Integral = 0.8

Derivative = 5



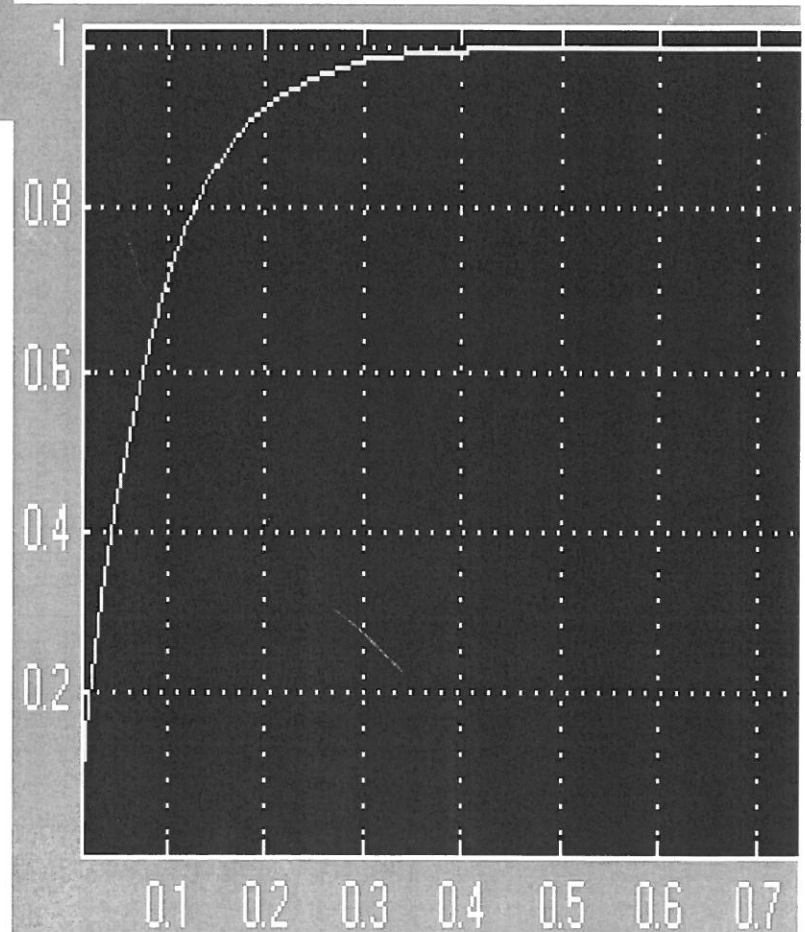
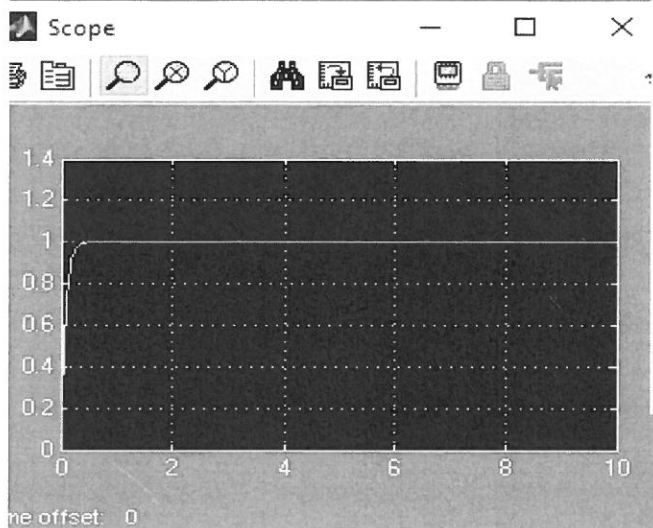


The third attempt seen me increasing the proportional to 10 and lowered the integral and derivative to see what the new outcome would be. This actually worked as seen by the screenshot. The overshoot has been resolved to none and the rise time is in the required parameters by reaching 0.9 on the Y axis before 0.2 on the X axis.

Proportional = 10

Integral = 0.3

Derivative = 0.8



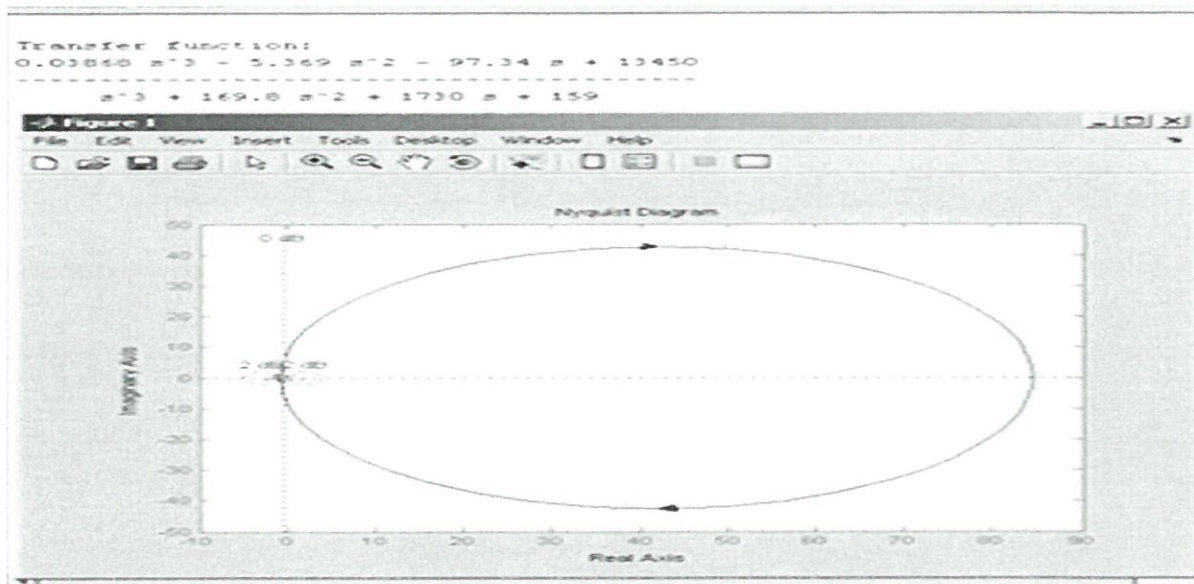
- 5) Write a Matlab file to plot the Nyquist diagram for the open loop transfer function of a servo control rig given below.

$$L(s) = \frac{0.03868s^3 - 5.369s^2 - 97.34s + 13450}{s^3 + 169.8s^2 + 1730s + 159}$$

```
% Task 5A Harry Owen
top=[0.03868 -5.369 -97.34 13450];
bot=[1 169.8 1730 159];

system=tf([top],[bot]) % Transfer function being created

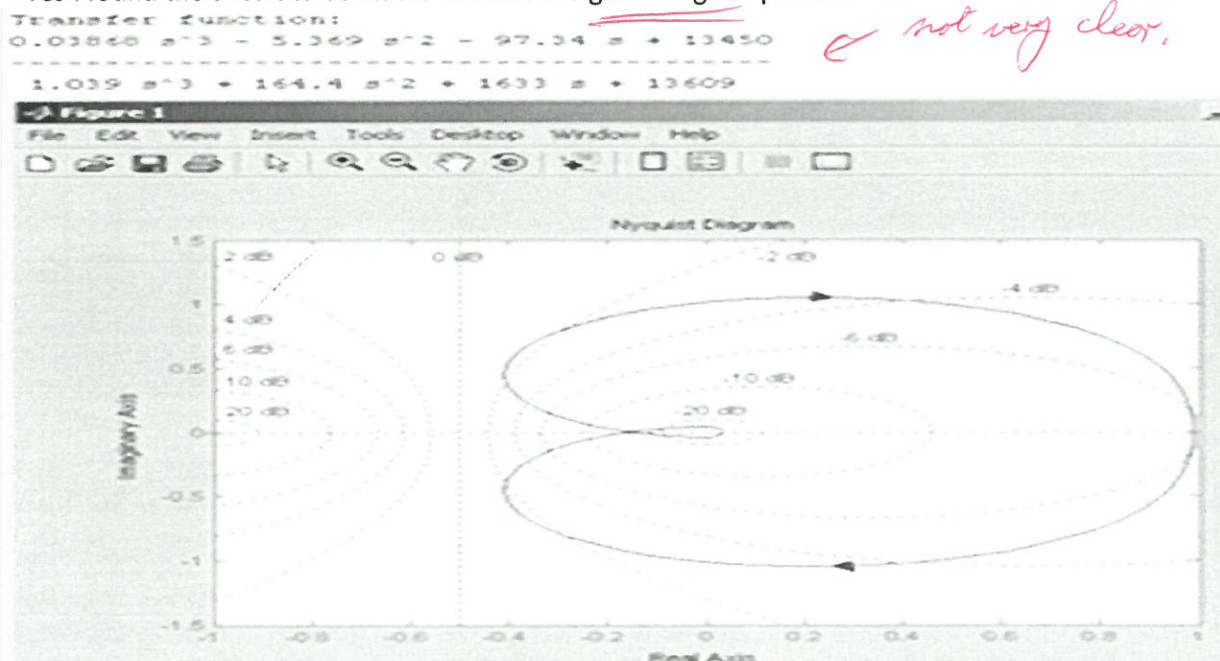
nyquist(system) % Plotting the Nyquist response
Grid
```



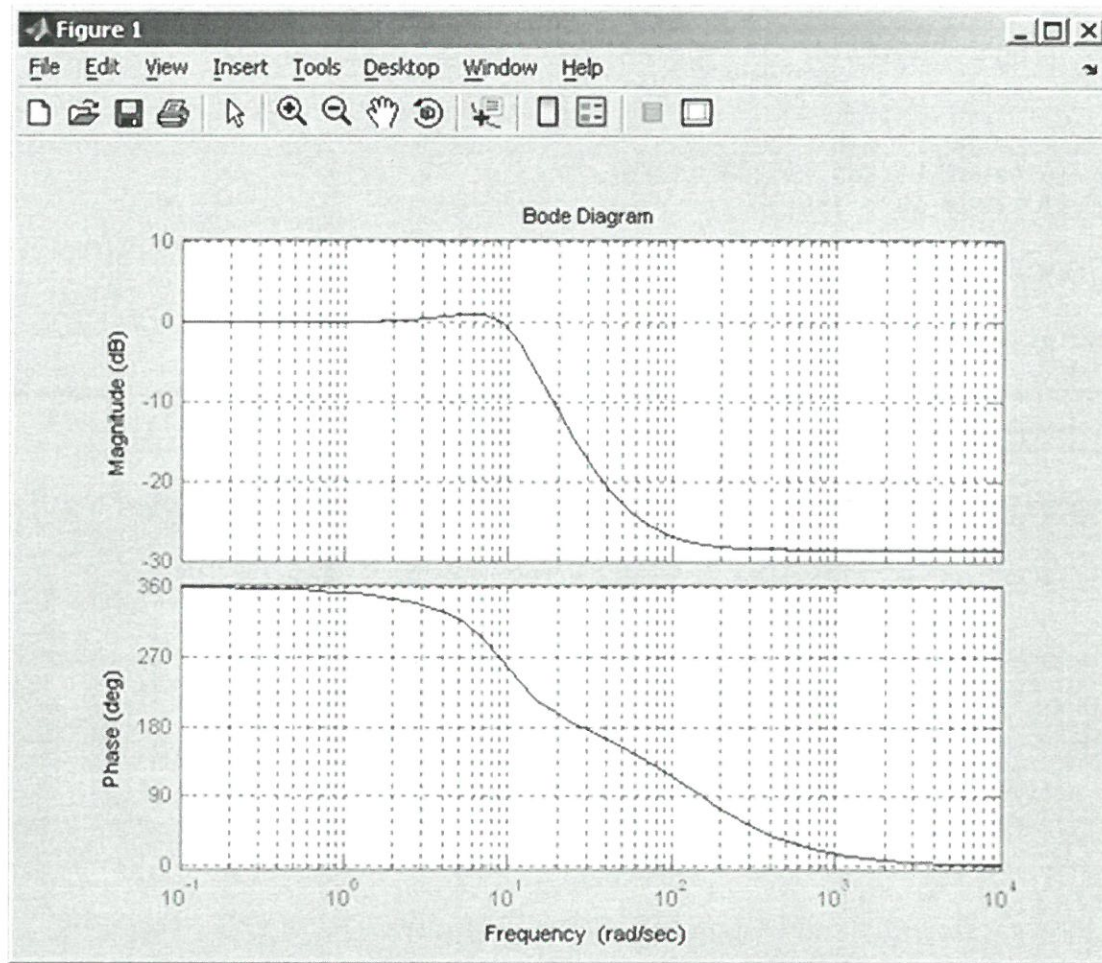
B) - Is the closed-loop system $L(s)/(1+L(s))$ stable? If yes, find the stability margins.

Yes I found the circuit to be stable because the gain margin is positive.

*← where is the gain margin.
 ← not very clear.*



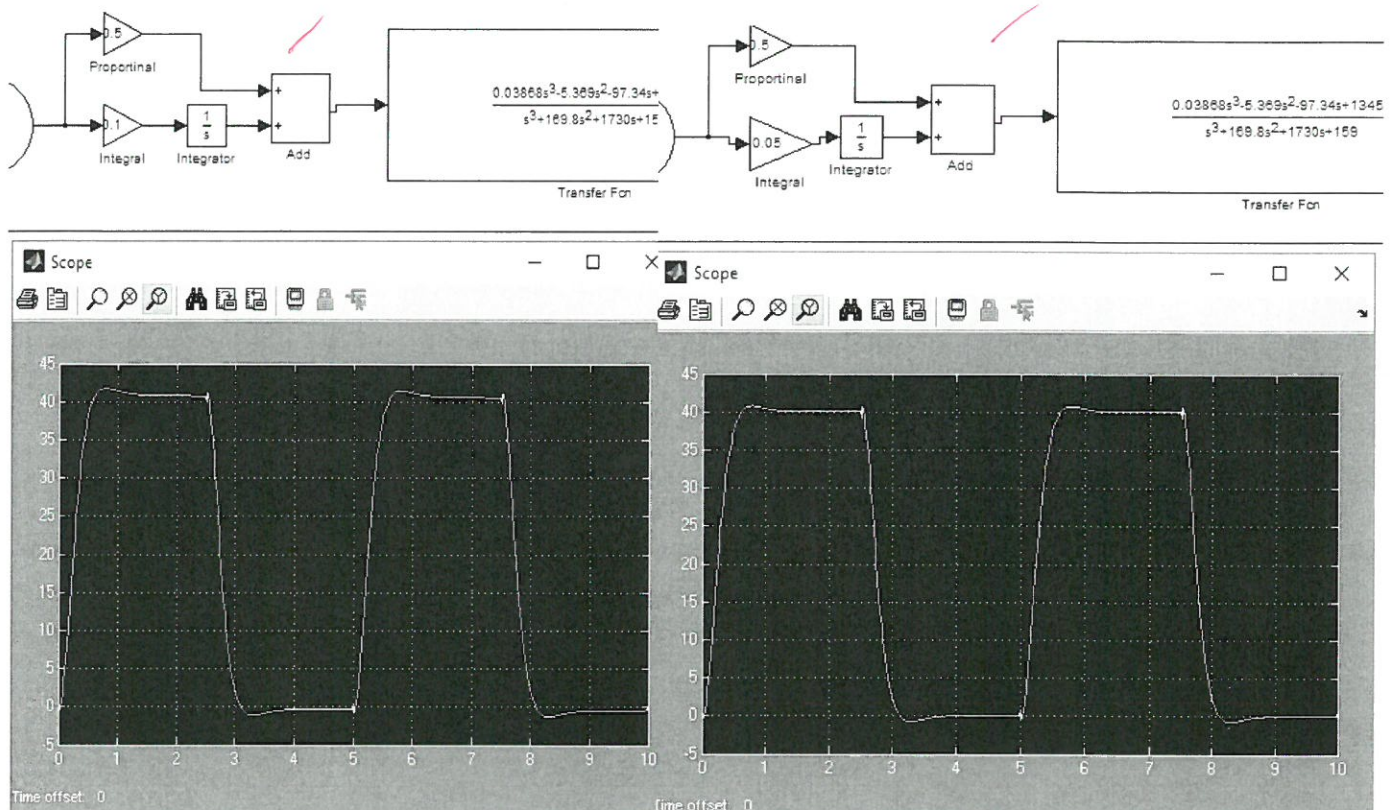
C) - Plot the Bode plot of the closed-loop transfer function $G_c(s) =$ and find the peak resonance M_p and bandwidth ω_b .



Peak resonance from the graph = $7M_p$ Hz

Bandwidth from the graph = $9-30 = 21$ Hz

D) - Build the system model with a PI controller gain and initial gains $K_i = 0.1$ and $K_p = 0.5$ in Simulink and then run the simulation. Plot the position response curve for the first 10 seconds if the reference position angle is a square wave with amplitude 40 degrees and frequency 0.2Hz. Manually tune the PI controller's gains in the Servo Control Rig so that the closed-loop system can achieve overshoot $\sigma < 5\%$ and settling time $t_s < 1.0\text{sec}$. Describe the tuning procedure in detail.



Proportional = 0.5 and integral = 0.1

Proportional = 0.5 and integral = 0.05

Have not explain how the system was tuned.

