



**ANKARA UNIVERSITY**  
**Engineering Faculty**  
**Department of Electrical and Electronics Engineering**

**Experiment-4**

**EEE 360 Control Lab**

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**PERFORMANCE OF**  
**FEEDBACK CONTROL SYSTEMS**

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**Objectives of the Experiment:**

- Learn basics of LabVIEW
- Construct feedback control systems ON Labview enviromen and time domain specifications of the systems
- Understand the impact of the parameter change on control system performance.
- Learn the Simulation window and related topics of LabVIEW

### 1.Preliminary Study:

1.Please read experimental study section to understand what you are going to do in the experiment.

2.Research on related topics in computer programs like Matlab or Scilab. Prepare yourself for the next questions and experiment. Learn and read related documents to understand the experiment.

3. Computer control of a robot to spray-paint an automobile is accomplished by the system shown in Figure 1. We wish to investigate the system when  $K = 1, 10, \text{ and } 20$ .

(a) For the three values of  $K$ , determine the percent overshoot, the settling time (with a 2% criterion), and the steady state error for a unit step input. Record your results in a table.

(b) Choose one of the three values of  $K$  that provides acceptable performance.

(c) For the value selected in part (b), determine the output for a disturbance  $T_d(s) = 1/s$  when  $R(s) = 0$ .

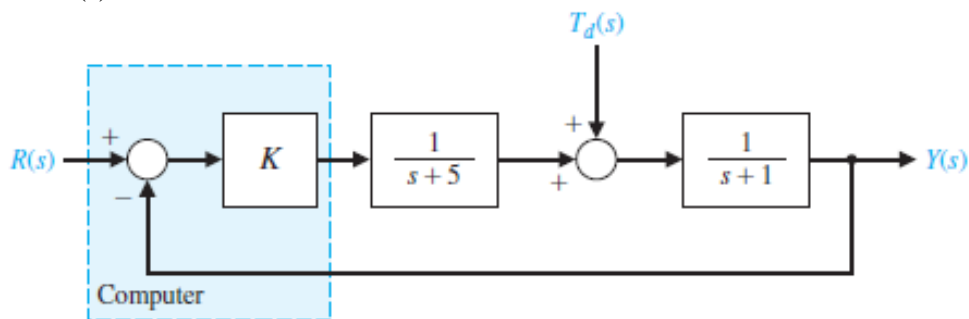


Figure 1. Control System of the Paint Robot

4. The roll control autopilot of an aircraft is shown in Figure. The goal is to select a suitable  $K$  so that the response to a step command  $\phi_d(t) = A, t \geq 0$ , will provide a response  $\phi(t)$  that is a fast response and has an percent overshoot of P.O. 20%

(a) Determine the closed-loop transfer function  $\phi(s) > \phi_d(s)$ .

(b) Determine the roots of the characteristic equation for  $K = 0.7, 3, \text{ and } 6$ .

(c) Using the concept of dominant roots, find the expected percent overshoot and peak time for the approximate second-order system.

(d) Plot the actual response and compare with the approximate results of part (c).

(e) Select the gain  $K$  so that the percent overshoot is P.O. = 16%. What is the resulting peak time?

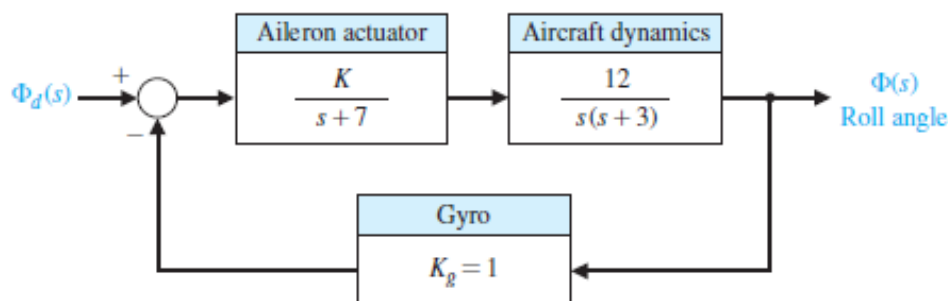


Figure 2. Roll Angle Control System

5.Consider the questions 3 and 4 and obtain output by using Matlab (or Scilab).

## 2.Experimental Study:

This section is given in two parts. The application in the first part (Repeat the Steps) is expected to be repeated by the student and to find the same result obtained. Thus, the student understands the subject and learns how to use it. In the second part (Do it Yourself), the jobs to be done are listed, but they are not explained how to do them. He solves and fills in the datasheet using the information (s)he learned in the first part and what he did in the preliminary study.

Look at the Experiment 1, 2, and 3 documents. Be sure you learn every step at the previous experiments. You may need the information from the previous experiment.

### 2.1. Repeat the Steps

Closed loop output of a second order system is given below. Two parameters damping ratio and natural frequency are key parameters of the output response.

$$Y(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} R(s).$$

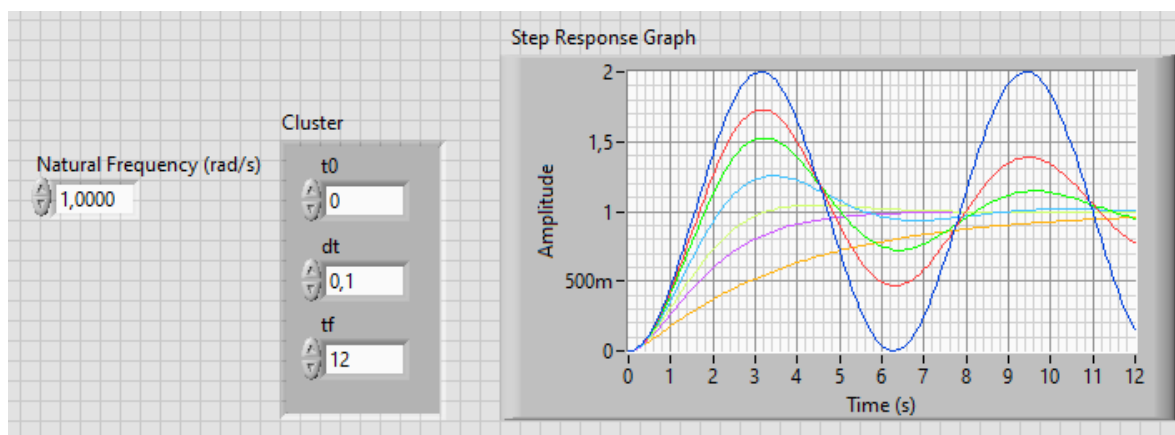
The impact of the damping ratio will be investigated on LabVIEW environment. For this purpose, CD Construct Special TF Model, CD Step Response will be used inside the **Control and Simulation** toolset. Figure 3 shows the Block Diagram and Front Panel for this problem.

#### **To include different damping ratio data into the loop at the same time:**

Select **Array Constant**. Then you will observe an empty box. Then add a **Constant Numerical** to this box. And finally find a small dot under the rectangle then drag this dot until there are 7 zeros. Also, at the entering point of the loop, right click and select **Enable Indexing**.

#### **To include all results to the step response graph:**

Add Build array to the Block Diagram windows. Find the small dot at the bottom of the symbol then drag it until two line is visible. Finally, right click to the symbol select **Concatenate Inputs**. One way of concatenating multiple arrays is by using Build Array function. This function works in two modes: either appending elements to an n-dimensional array, which is the default mode, or concatenating multiple arrays.



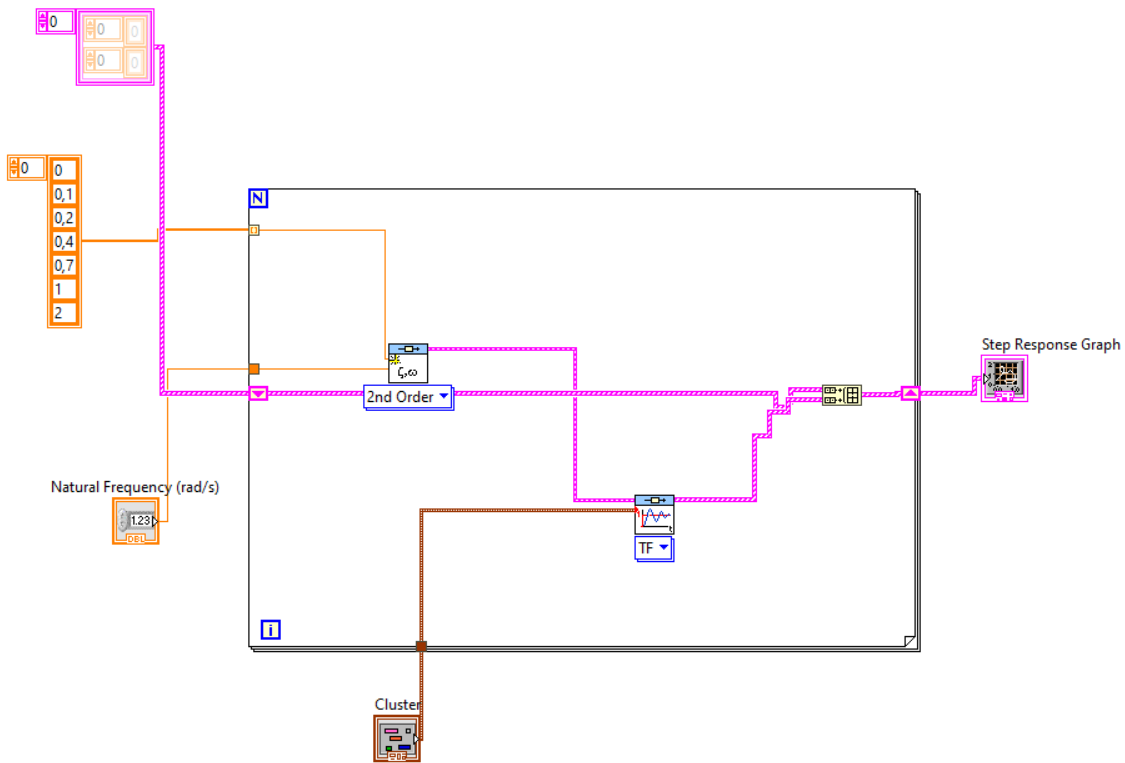


Figure 3. Block diagram and Front panel for the problem

Previously we discuss the simulation by using the loop tool and same control system toolbox symbols. However, if the Control and Simulation Module is implemented on LabVIEW, it is possible to make these implementations easier. For this purpose, consider the following system in Figure 4.

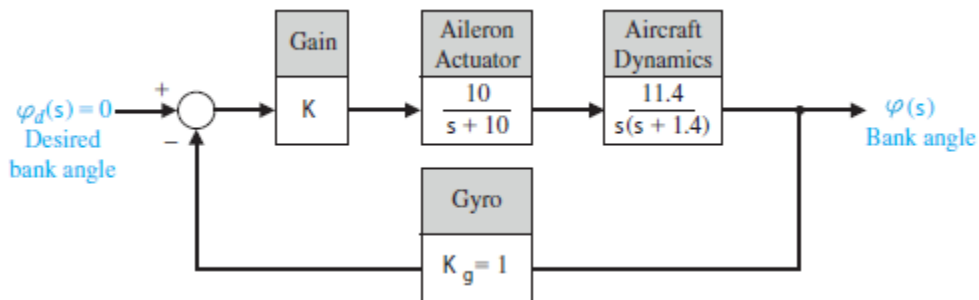


Figure 4. Control System

Find **Control and Simulation -> Simulation ->Control and Simulation Loop**. This loop operated like a Simulink module in Matlab. It is possible to add the blocks given in Figure 4 inside to the new loop.

Find **Control and Simulation -> Simulation ->Signal Generation->Step**: The step input module for the simulation.

Find **Control and Simulation -> Simulation ->Signal Arithmetic->Summation**: it is the summing junction. It is possible to change + and – signs and their numbers.

Find **Control and Simulation -> Simulation ->Signal Arithmetic->Controller Gain**: A single multiplier like K in a simple controller.

Find **Control and Simulation -> Simulation ->Continuous linear System->Transfer Function**: It is possible to include every transfer function by using this block. Double Click on the block as given in Figure 5.

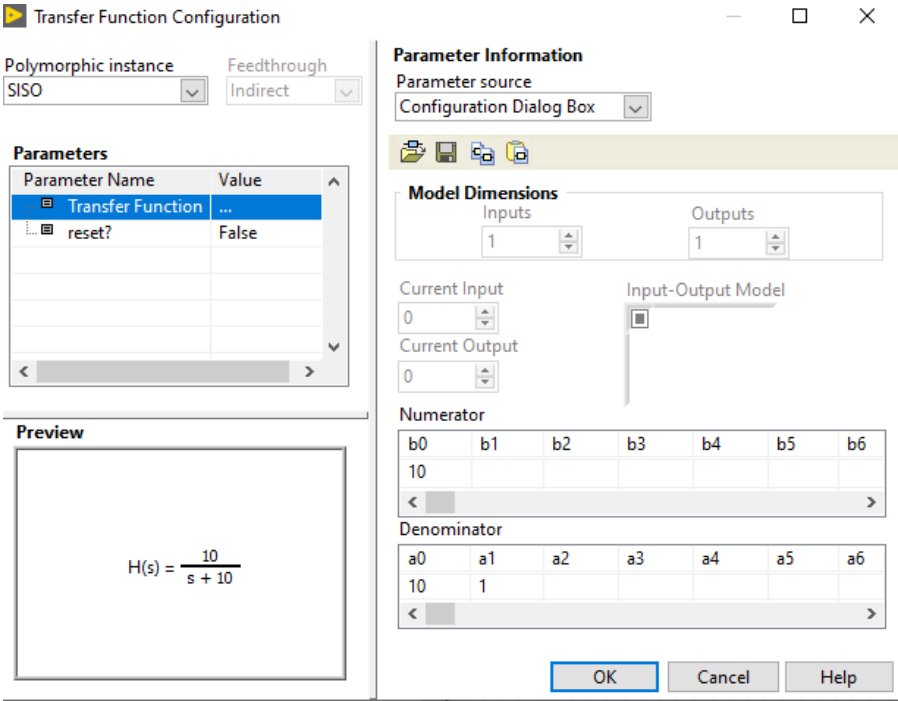


Figure 5. Transfer Function Configurations

Find **Control and Simulation -> Simulation ->Graph Utilities->SimTime Waveform**: This symbol collects data to make it ready to display. To display this data Waveform Char automatically added to the window

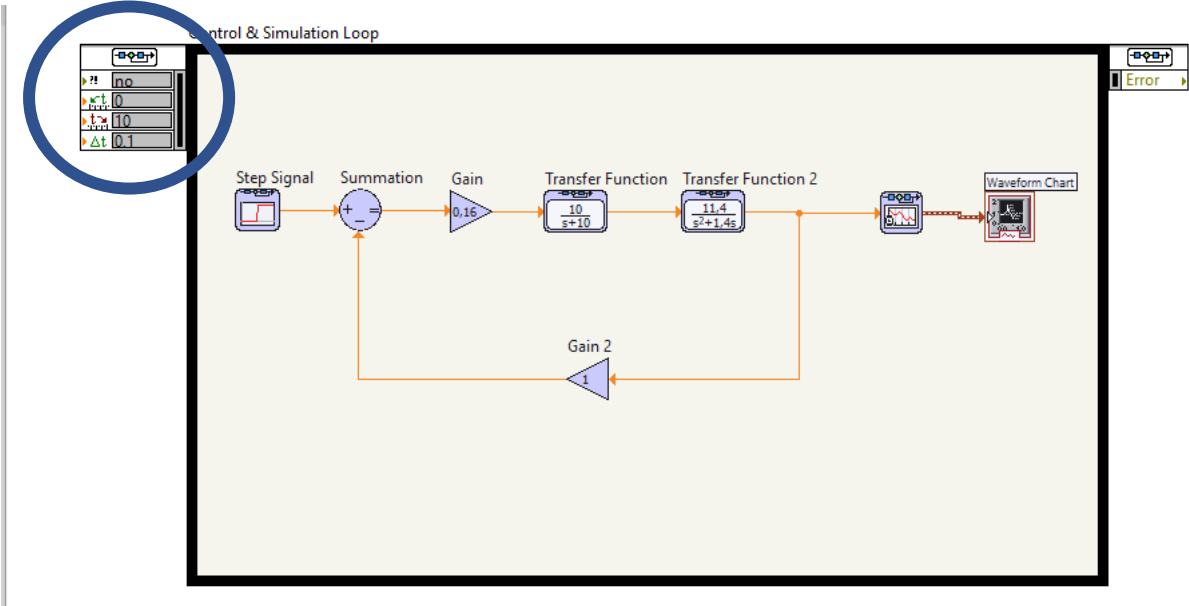


Figure 6. Block Diagram display of the implementation

Look at the left rectangle (inside the circle) on the left of the Simulation Environment. Find the small rectangle and drag it until some of the properties are displayed. Then you can double click to change the properties. Therefore, you will observe **Configure Simulation Parameters** window (Figure 7).

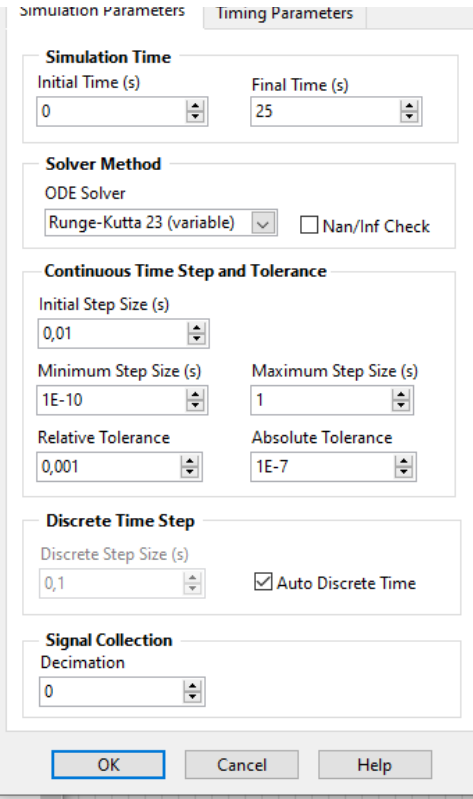


Figure 7. Simulation Parameters.

You can change simulation parameters from this window. For now, just change final time of the simulation. Now you can run the simulation. However, the display format only gives the last data of the output. To get the overall output signal right click on Waveform Chart and select properties. The Properties window is given in Figure 8.

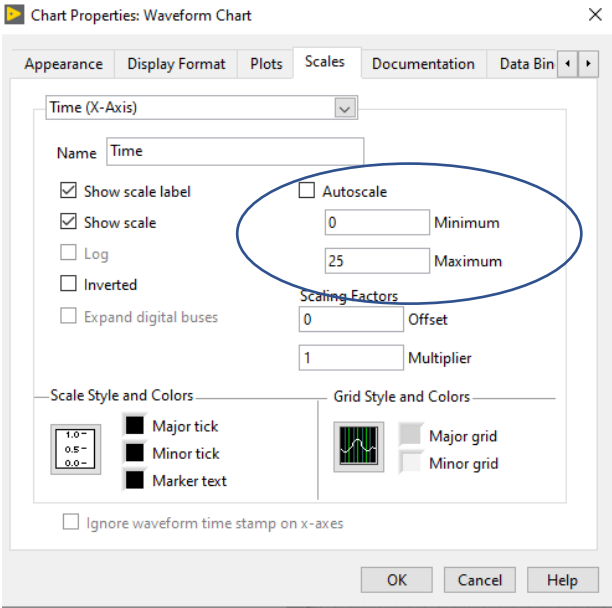


Figure 8. Waveform Properties.

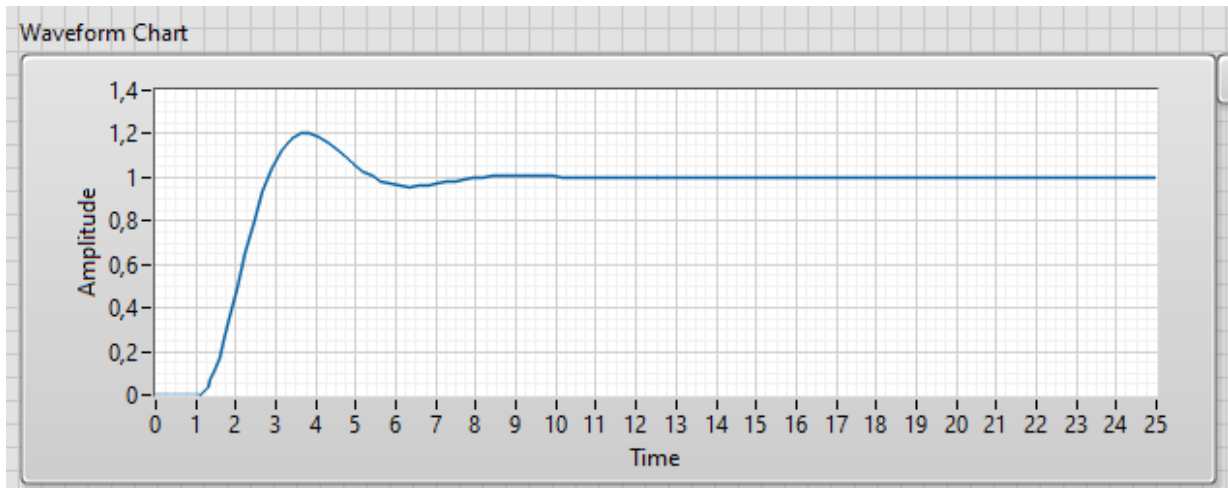


Figure 9. Output Signal.

Now you can run the code and Figure 9 displays the output signal for the system given in Figure 4.

## **2.2. Do it Yourself!**

1. Consider the system given in preliminary work Figure 1. Construct the circuit on LabVIEW
  - a) Assume that  $T_d=0$  and input is step function. Look at the Table in B1 and fill the table
  - b) For  $K = 10$ , plot the output to A1
  - c) Assume that input=0 and  $t_d$  is step function. Look at the Table in B2 and fill the table
  - d) For  $K = 10$ , plot the output to A2
  - e) Comment on How the parameter  $K$  effect the output of the system.
  
2. Consider the system given in preliminary work Figure 2. Construct the circuit on LabVIEW
  - a) Assume that input is step function. Look at the Table in B3 and fill the table
  - b) For  $K = 3$ , plot the output to A3
  - c) Comment on How the parameter  $K$  effect the output of the system.

**Data Sheet (Student Copy):**

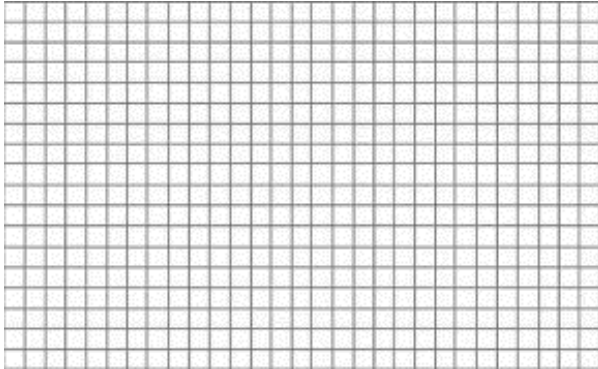
B1

K	Settling Time	Overshoot	Steady State Error
1			
5			
10			
20			

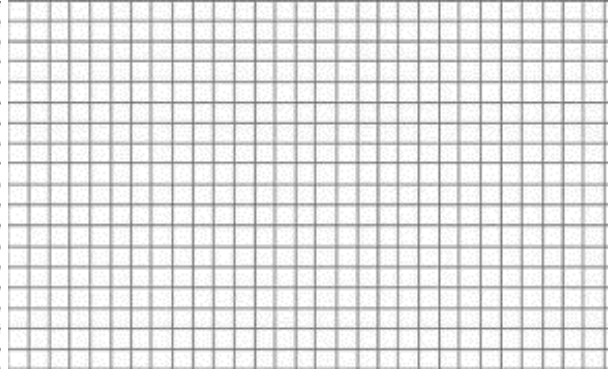
B2

K	Settling Time	Overshoot	Steady State Error
1			
5			
10			
20			

A1



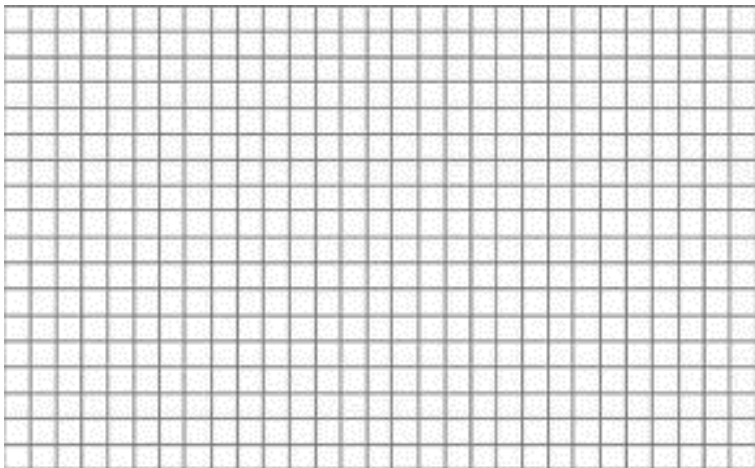
A2



B3

K	Settling Time	Overshoot	Steady State Error
0.3			
0.7			
3			
6			

A3





Names of students in the group:

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**Data Sheet (Instructor Copy):**

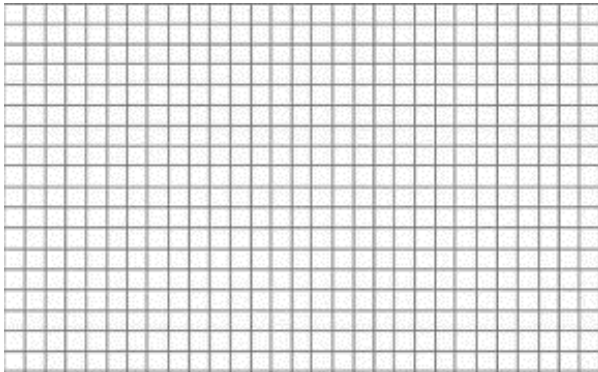
B1

K	Settling Time	Overshoot	Steady State Error
1			
5			
10			
20			

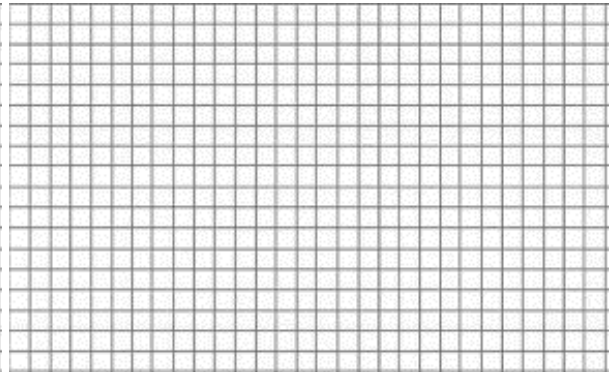
B2

K	Settling Time	Overshoot	Steady State Error
1			
5			
10			
20			

A1



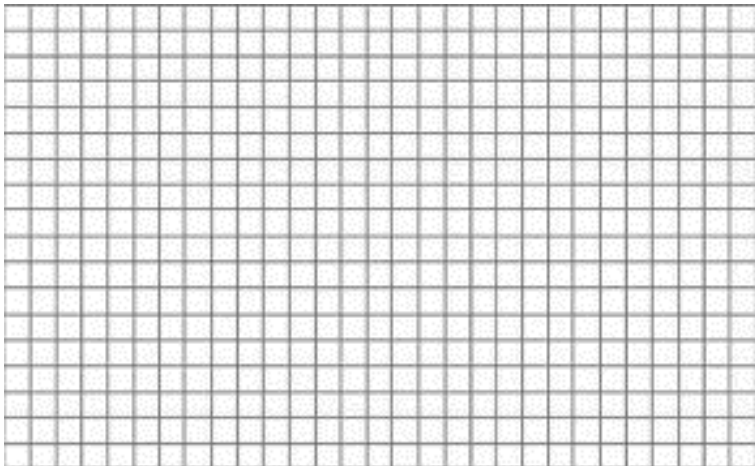
A2



B3

K	Settling Time	Overshoot	Steady State Error
0.3			
0.7			
3			
6			

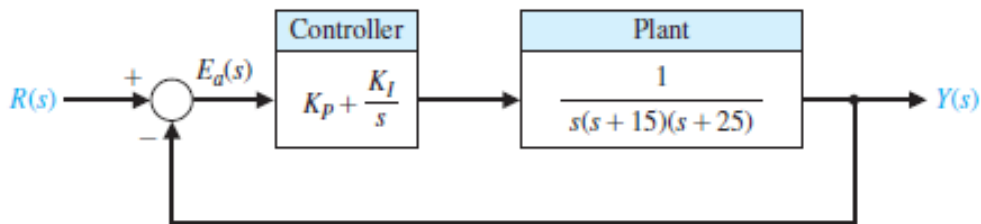
A3



**Report:**

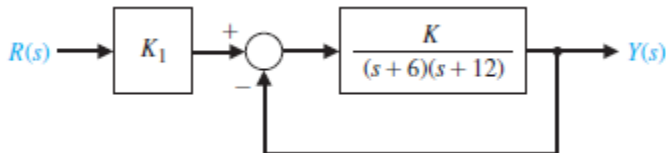
1. Please answer all the questions give in experimental study. Please use Data Sheet you obtained from the experiment.
2. Re-make the calculations in preliminary study questions 3 and 4.
3. Explain your outcomes from the experiment.
4. The unity negative feedback system in Figure has the process given by

$$G(s) = \frac{1}{s(s + 15)(s + 25)}$$



The controller is a proportional plus integral controller with gains  $K_p$  and  $K_I$ . The objective is to design the controller gains such that the dominant roots have a damping ratio equal to 0.707. Determine the resulting peak time and settling time (with a 2% criterion) of the system to a unit step input. Use Matlab (or Scilab) to design the controller.

5. The system is shown in Figure.



- (a) Determine the steady-state error for a unit step input in terms of  $K$  and  $K_1$ , where  $E(s) = R(s) - Y(s)$ .
- (b) Select  $K_1$  so that the steady-state error is zero.