LAB #2 PID Control using MATLAB/Simulink Simulations

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IN FULFILLMENT OF THE REQUIREMENTS FOR:
MTRE 4002L

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Contents

1. INTRODUCTION

The goal of this lab is to serve as an introduction to PID controllers. This was done my building several systems that included the different parts of the PID controller to build up to the final full PID controller. The systems built are the following, P, PI, PD, and finally the full PID controller.

2. QUESTION 1 – P Controller

In question 1 we built a basic P controller. Various parameters were given to analyze of which the results are recorded in Table 1. From looking at the trend of the graphs, it can be seen that K_p impacts how fast the response has its rise time most aggressively.

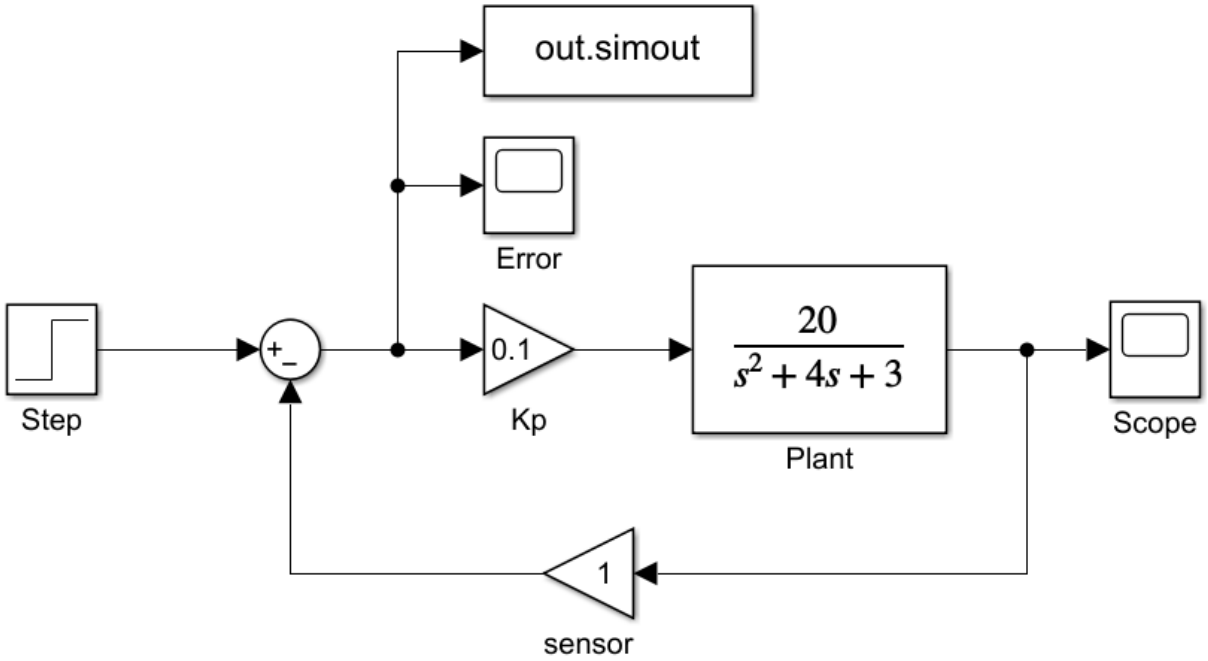
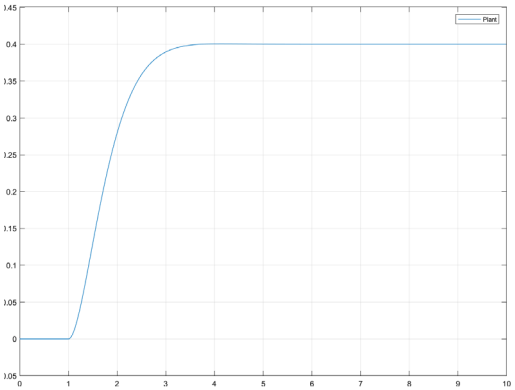
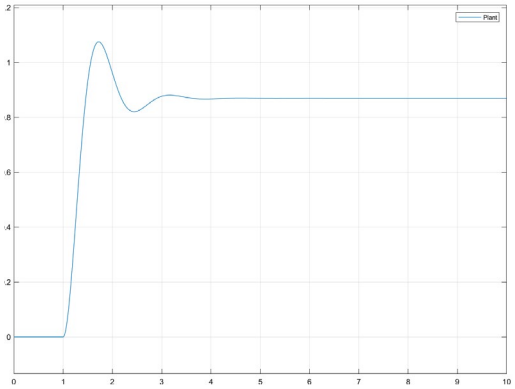


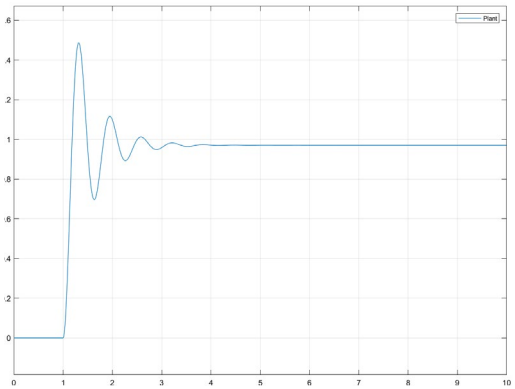
Figure 1



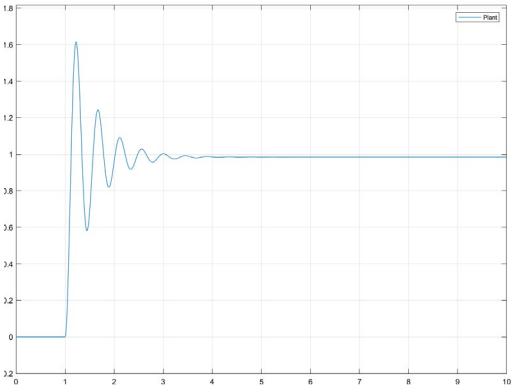
RiseTime:	1.2782
SettlingTime:	3.0749
SettlingMin:	0.3608
SettlingMax:	0.4007
Overshoot:	0.1867
Undershoot:	0
Peak:	0.4007
PeakTime:	4.1400



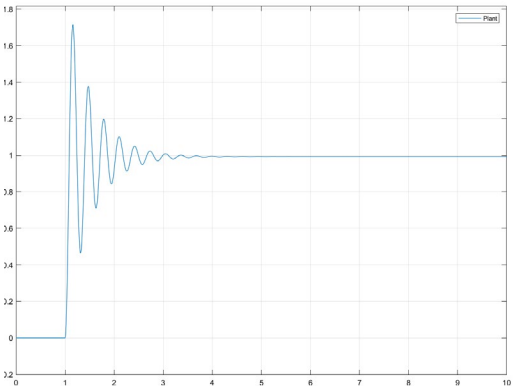
RiseTime:	0.3108
SettlingTime:	2.7517
SettlingMin:	0.7996
SettlingMax:	1.0753
Overshoot:	23.6580
Undershoot:	0
Peak:	1.0753
PeakTime:	1.7200



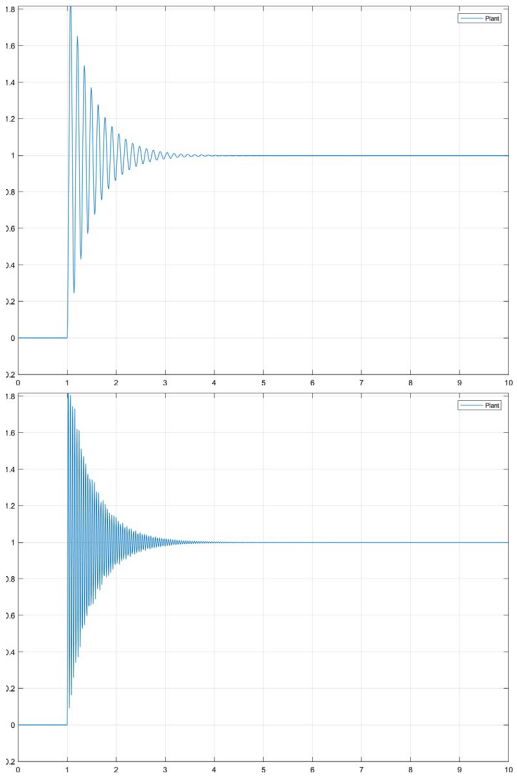
RiseTime:	0.1185
SettlingTime:	2.9438
SettlingMin:	0.6963
SettlingMax:	1.4867
Overshoot:	53.1308
Undershoot:	0
Peak:	1.4867
PeakTime:	1.3200



RiseTime:	0.0804
SettlingTime:	2.8391
SettlingMin:	0.5817
SettlingMax:	1.6159
Overshoot:	64.0090
Undershoot:	0
Peak:	1.6159
PeakTime:	1.2200



RiseTime:	0.0553
SettlingTime:	2.9129
SettlingMin:	0.4657
SettlingMax:	1.7162
Overshoot:	72.9028
Undershoot:	0
Peak:	1.7162
PeakTime:	1.1600



RiseTime: 0.0236
SettlingTime: 2.9069
SettlingMin: 0.2449
SettlingMax: 1.8660
Overshoot: 86.8822
Undershoot: 0
Peak: 1.8660
PeakTime: 1.0700

RiseTime: 0.0086
SettlingTime: 3.0177
SettlingMin: 0.0914
SettlingMax: 1.9033
Overshoot: 90.3539
Undershoot: 0
Peak: 1.9033
PeakTime: 1.0246

Table 1

Proportional Gain (k_p)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
0.1	1.2782	4.1400	3.0749	0.1867	0.6000	Yes	Critically Damped
1	0.3108	1.7200	2.7517	23.6580	0.1304	Yes	Under Damped
5	0.1185	1.3200	2.9438	53.1308	0.0291	Yes	Under Damped
10	0.0804	1.2200	2.8391	64.0090	0.0148	Yes	Under Damped
20	0.0553	1.1600	2.9129	72.9028	0.0074	Yes	Under Damped
100	0.0236	1.0700	2.9069	86.8822	0.0015	Yes	Under Damped
1000	0.0086	1.0246	3.0177	90.3539	1.50e-4	Yes	Under Damped

3. QUESTION 2 – PI Controller

In question 2 we built a basic PI controller. Various parameters were given to analyze of which the results are recorded in Table 2. Please note that some responses in this set proved to go out of bounds of the graph which resulted in inaccurate results for some values. These values have been put in italics to mark their inaccuracy. These values are kept due to keeping consistently with what MATLAB outputs. It must be noted that when a response to go out of bounds of the plot it will never reach a steady state. It can be assumed that K_i is the parameter that effects the steady state error portion of the response as when that value is increased the response oscillates and may even go out of the bounds of the plot.

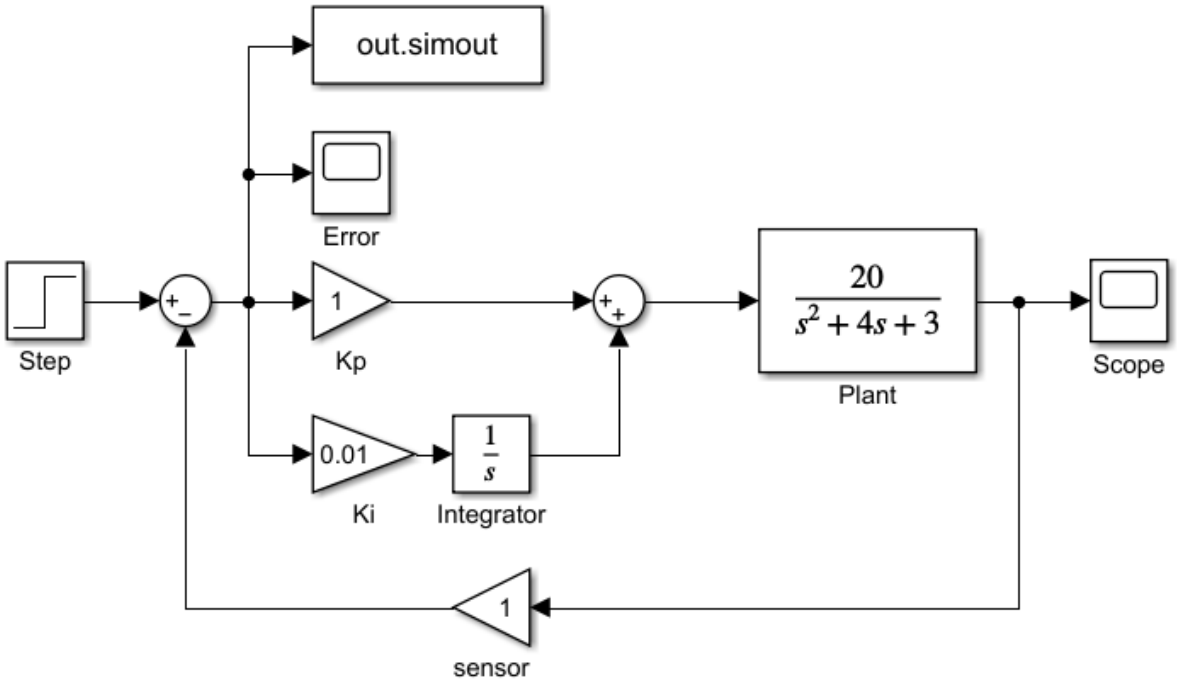
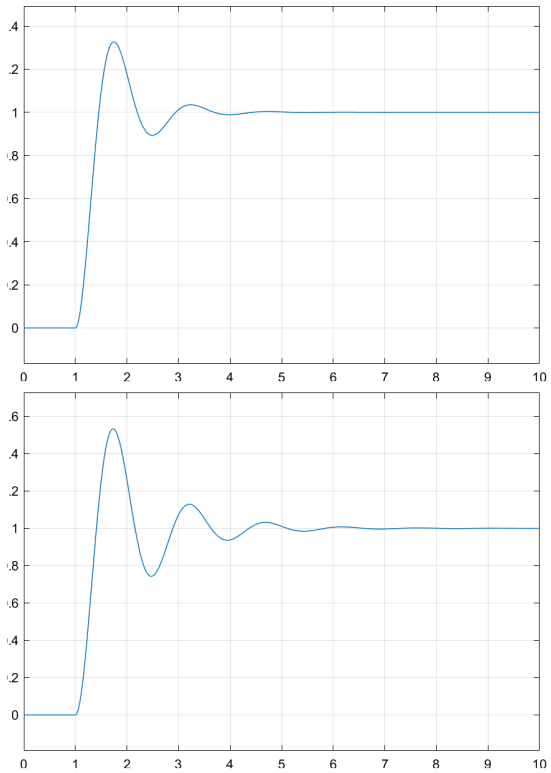
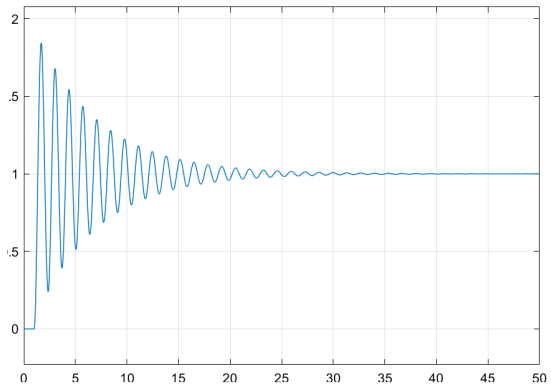


Figure 2

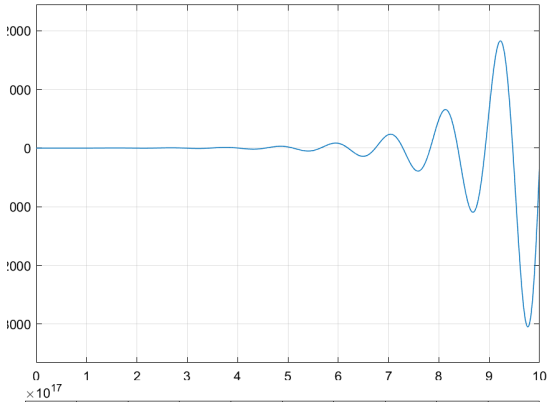


RiseTime:	0.3061
SettlingTime:	3.4798
SettlingMin:	0.8932
SettlingMax:	1.3267
Overshoot:	32.6706
Undershoot:	0
Peak:	1.3267
PeakTime:	1.7500

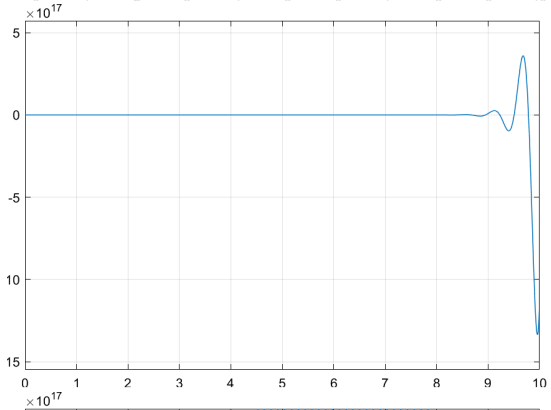
RiseTime:	0.2722
SettlingTime:	4.9069
SettlingMin:	0.7430
SettlingMax:	1.5330
Overshoot:	53.3309
Undershoot:	0
Peak:	1.5330
PeakTime:	1.7300



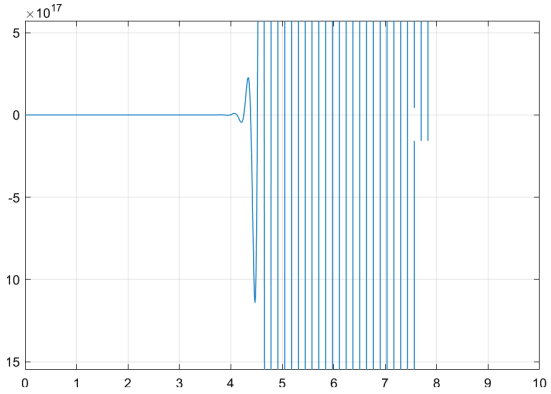
RiseTime: 0.2325
SettlingTime: 24.0007
SettlingMin: 0.2399
SettlingMax: 1.8444
Overshoot: 84.4067
Undershoot: 0
Peak: 1.8444
PeakTime: 1.6800



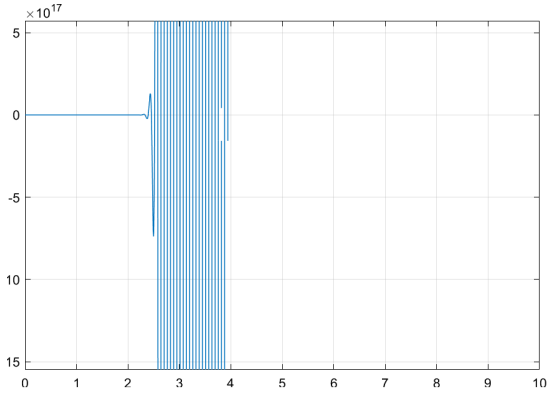
RiseTime: *2.1998*
SettlingTime: *9.9974*
SettlingMin: *-3.0496e+03*
SettlingMax: *1.8290e+03*
Overshoot: *991.7894*
Undershoot: *654.8151*
Peak: *3.0496e+03*
PeakTime: *9.7700*



RiseTime: *0.0983*
SettlingTime: *9.9963*
SettlingMin: *-1.3361e+18*
SettlingMax: *-1.0522e+18*
Overshoot: *15.7082*
Undershoot: *31.1786*
Peak: *1.3361e+18*
PeakTime: *9.9600*



RiseTime: *0.0355*
SettlingTime: *9.9989*
SettlingMin: *-1.4831e+47*
SettlingMax: *-1.4831e+47*
Overshoot: *0*
Undershoot: *33.1838*
Peak: *1.4831e+47*
PeakTime: *10*



RiseTime: *0.0223*
SettlingTime: *9.9993*
SettlingMin: *2.6651e+108*
SettlingMax: *3.3622e+108*
Overshoot: *26.1570*
Undershoot: *22.3372*
Peak: *3.3622e+108*
PeakTime: *9.9897*

Table 2

Proportional Gain (k_p)	Integral Gain (k_i)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
1	1	0.3061	1.7500	3.4798	32.6706	1.44e-6	Yes	Under Damped
1	2	0.2711	1.7300	4.9069	53.3309	1.94e-4	Yes	Under Damped
1	4	0.2325	1.6800	24.0007	84.4067	*-0.1041*	Yes	Under Damped
1	10	*2.1998*	*9.7700*	*9.9974*	*991.7894*	*280.3184*	*No*	*Under Damped*
1	100	*0.0983*	*9.9600*	*9.9963*	*15.7082*	*1.15e+18*	*No*	*Under Damped*
1	1000	*0.0355*	*10*	*9.9989*	*0*	*1.48e+47*	*No*	*Under Damped*
1	10000	*0.0223*	*9.9897*	*9.9993*	*26.1570*	*-2.66e+108*	*No*	*Under Damped*

4. QUESTION 3 – PD Controller

In question 3 we built a basic PD controller. Various parameters were given to analyze of which the results are recorded in Table 3. K_d can be analyzed to affect the time to reach steady state. This effect can be clearly seen the further down in Table 3. As this parameter is increased the settling time becomes very large.

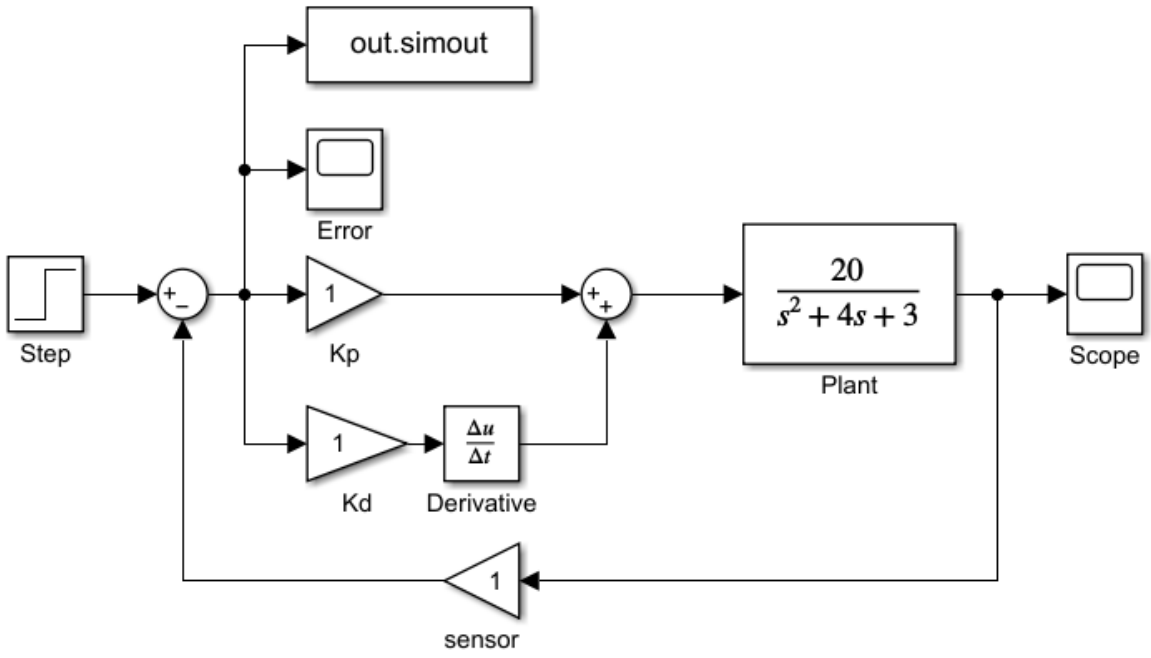
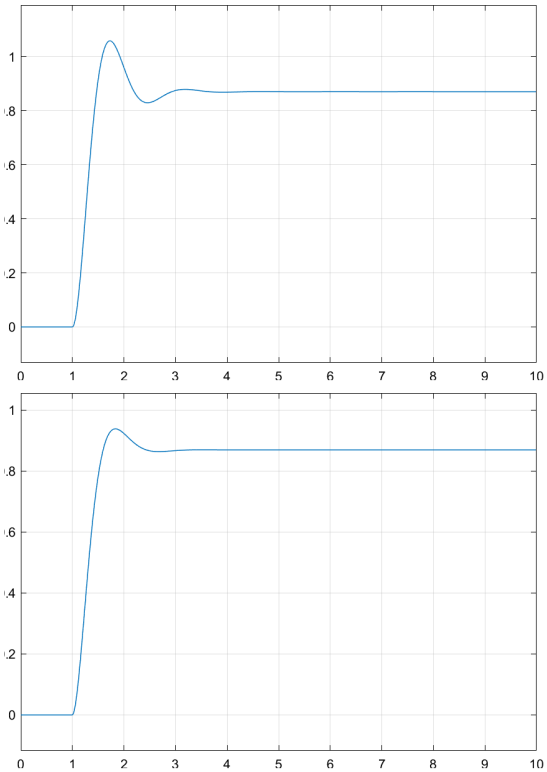
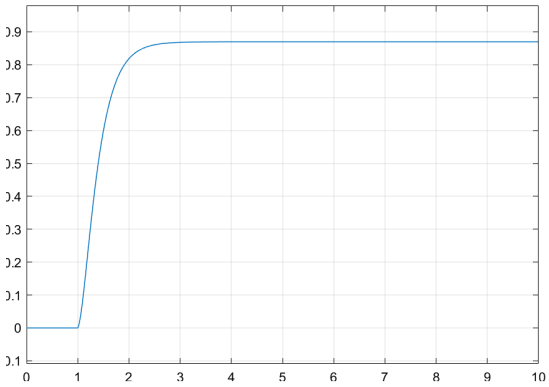


Figure 3

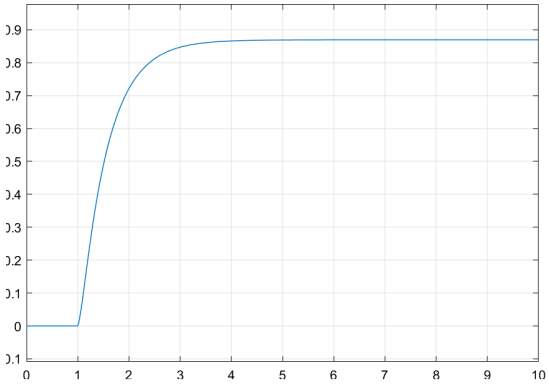


RiseTime:	0.3181
SettlingTime:	2.7448
SettlingMin:	0.7921
SettlingMax:	1.0577
Overshoot:	21.6334
Undershoot:	0
Peak:	1.0577
PeakTime:	1.7234

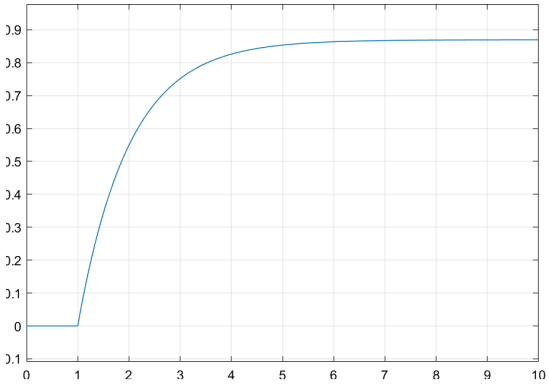
RiseTime:	0.3997
SettlingTime:	2.2400
SettlingMin:	0.7877
SettlingMax:	0.9388
Overshoot:	7.9587
Undershoot:	0
Peak:	0.9388
PeakTime:	1.8334



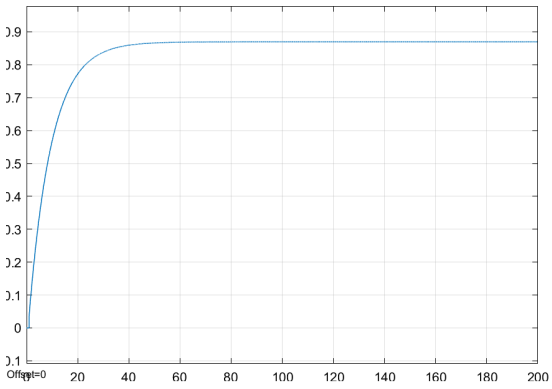
RiseTime: 0.7470
SettlingTime: 2.3113
SettlingMin: 0.7851
SettlingMax: 0.8696
Overshoot: 0
Undershoot: 0
Peak: 0.8696
PeakTime: 10



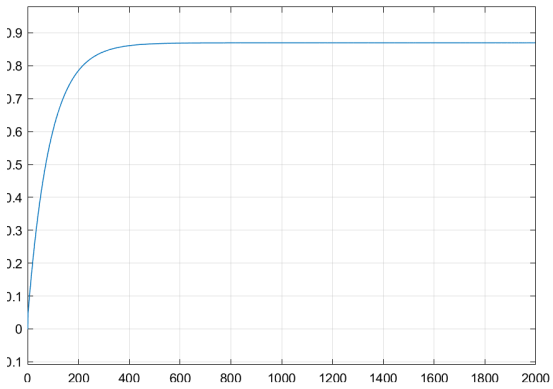
RiseTime: 1.1838
SettlingTime: 3.1331
SettlingMin: 0.7829
SettlingMax: 0.8696
Overshoot: 0
Undershoot: 0
Peak: 0.8696
PeakTime: 10



RiseTime: 2.2018
SettlingTime: 4.9141
SettlingMin: 0.7832
SettlingMax: 0.8695
Overshoot: 0
Undershoot: 0
Peak: 0.8695
PeakTime: 10



RiseTime: 19.4910
SettlingTime: 35.2625
SettlingMin: 0.7829
SettlingMax: 0.8696
Overshoot: 0.0105
Undershoot: 0
Peak: 0.8696
PeakTime: 199.9646



RiseTime: 191.4564
SettlingTime: 337.9327
SettlingMin: 0.7826
SettlingMax: 0.8696
Overshoot: 0
Undershoot: 0
Peak: 0.8696
PeakTime: 2000

Table 3

Proportional Gain (k_p)	Derivative Gain (k_d)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
1	0.01	0.3181	1.0577	2.7448	21.6334	0.1304	Yes	Under Damped
1	0.1	0.3997	1.8334	2.2400	7.9587	0.1304	Yes	Under Damped
1	0.3	0.7470	10	2.3113	0	0.1304	Yes	Critically Damped
1	0.5	1.1838	10	3.1331	0	0.1304	Yes	Over Damped
1	1	2.2018	10	4.9141	0	0.1306	Yes	Over Damped
1	10	19.4910	199.9646	35.2625	0.0105	0.1305	No	Over Damped
1	100	191.4564	2000	337.9327	0	0.1304	Yes	Over Damped

5. QUESTION 4 – PID Controller

In question 4 we built a basic PID controller. Various parameters were given to analyze of which the results are recorded in Table 4. Incorporating all three of these parameters we are given a highly tunable controller. With the responses given one can see that we have a plethora of different characteristics that might be desirable in many different applications.

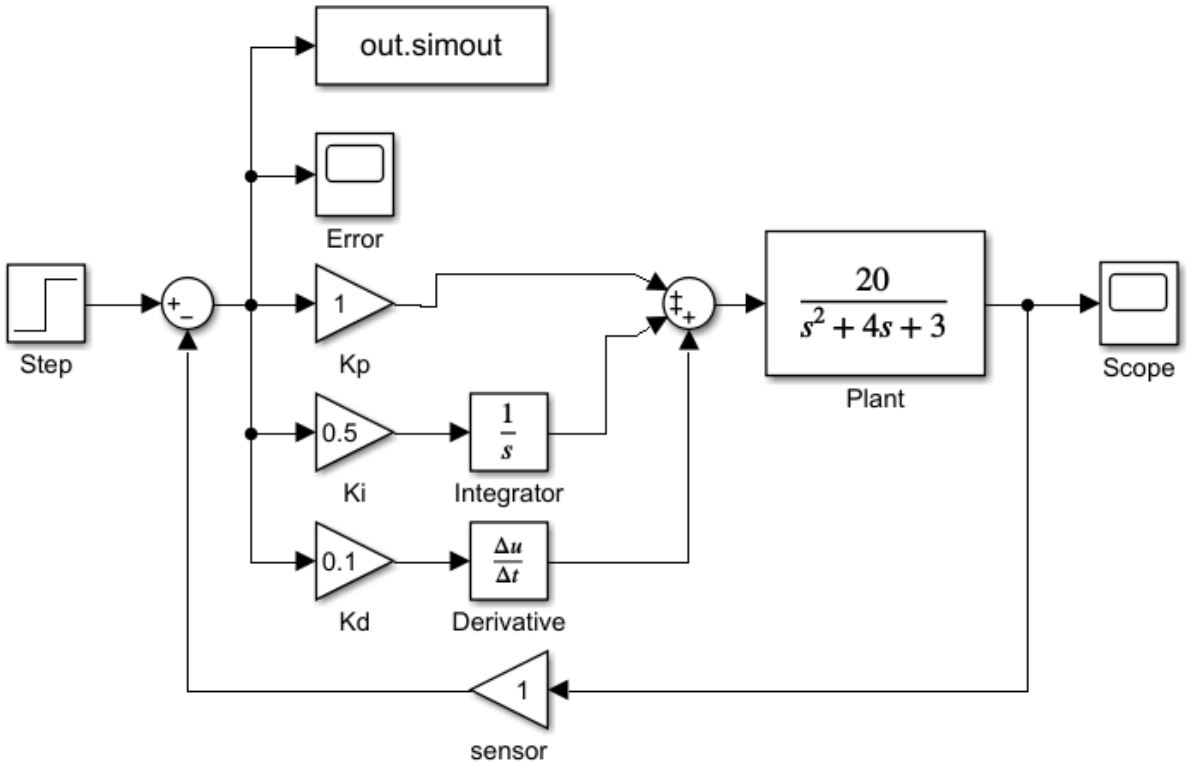
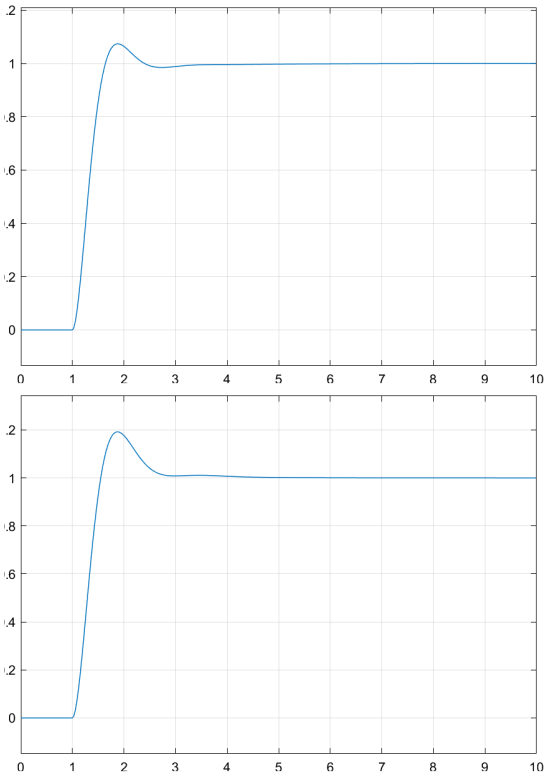
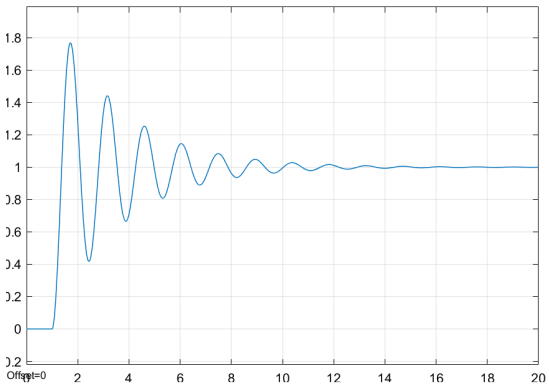


Figure 4

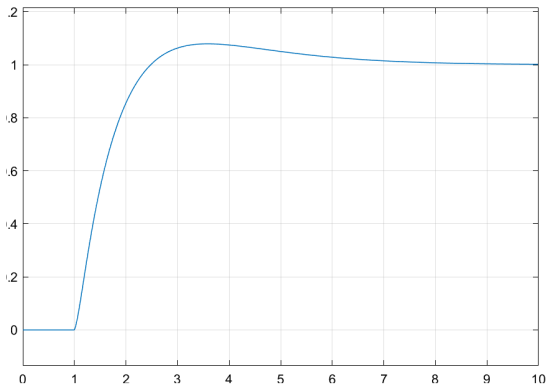


RiseTime: 0.4272
SettlingTime: 2.2524
SettlingMin: 0.9110
SettlingMax: 1.0735
Overshoot: 7.3782
Undershoot: 0
Peak: 1.0735
PeakTime: 1.8834

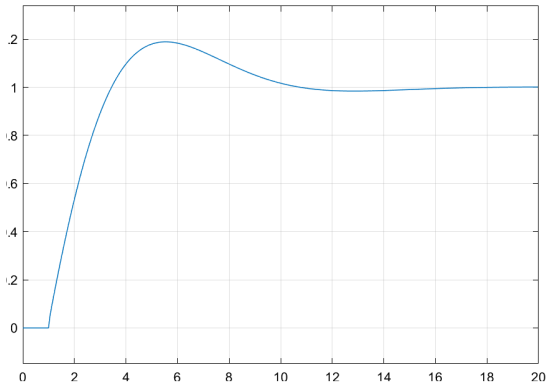
RiseTime: 0.3775
SettlingTime: 2.6532
SettlingMin: 0.9005
SettlingMax: 1.1919
Overshoot: 19.1920
Undershoot: 0
Peak: 1.1919
PeakTime: 1.8734



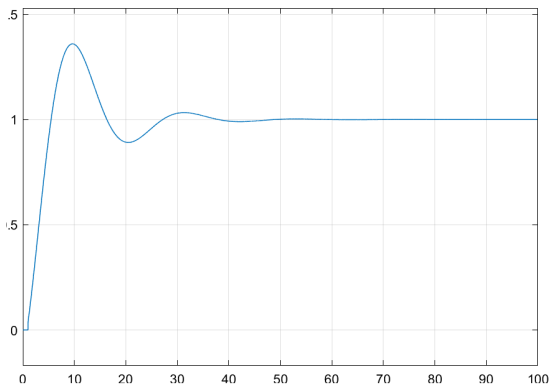
RiseTime:	0.2477
SettlingTime:	11.1522
SettlingMin:	0.4175
SettlingMax:	1.7686
Overshoot:	76.9313
Undershoot:	0
Peak:	1.7686
PeakTime:	1.7134



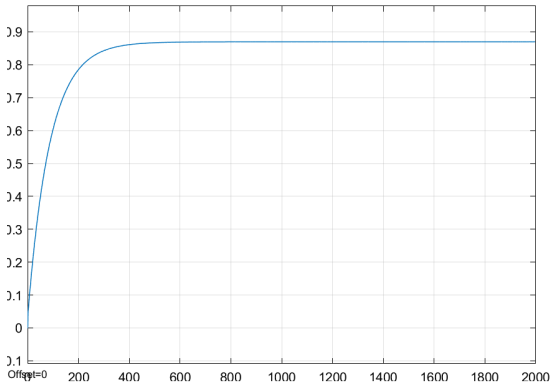
RiseTime:	1.0070
SettlingTime:	6.4249
SettlingMin:	0.9044
SettlingMax:	1.0789
Overshoot:	7.7073
Undershoot:	0
Peak:	1.0789
PeakTime:	3.5834



RiseTime:	1.8912
SettlingTime:	9.8503
SettlingMin:	0.9023
SettlingMax:	1.1890
Overshoot:	18.7495
Undershoot:	0
Peak:	1.1890
PeakTime:	5.5334



RiseTime:	3.6157
SettlingTime:	34.6526
SettlingMin:	0.8912
SettlingMax:	1.3599
Overshoot:	35.9871
Undershoot:	0
Peak:	1.3599
PeakTime:	9.6497



RiseTime:	191.4194
SettlingTime:	337.7783
SettlingMin:	0.7826
SettlingMax:	0.8696
Overshoot:	0.0036
Undershoot:	0
Peak:	0.8696
PeakTime:	1.9999e+03

Table 4

Proportional Gain (k_p)	Integral Gain (k_i)	Derivitive Gain (k_d)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/Critically damped System?)
1	0.5	0.1	0.4272	1.8834	2.2524	7.3782	1.57e-6	Yes	Under Damped
1	1	0.1	0.3775	1.8734	2.6432	19.1920	-6.34e-11	Yes	Under Damped
1	5	0.1	0.2477	1.7134	11.1522	76.9313	3.91e-4	Yes	Under Damped
1	0.5	0.5	1.0070	3.5834	6.4249	7.7073	-5.69e-7	Yes	Under Damped
1	0.5	1.5	1.8912	5.5334	9.8503	18.7495	-0.013	Yes	Under Damped
1	0.5	5	3.6157	9.6497	0.8912	35.9871	-1.36e-5	Yes	Under Damped
1	0	100	191.4194	1.9999e+03	337.7783	0.0036	0.1305	Yes	Critically Damped

6. CONCLUSION

In conclusion, this lab was a very helpful exercise in visualizing what each component does in a PID controller. Understanding each component on their own was enlightening and will certainly aid in designing controllers. Additionally, this has shown to show the power of MATLAB in analyzing PID controllers.