Contents


```
%%Prelab6c
M = 0.94;
m = 0.23;
Lp = 0.3302;
r = 6.36*10^-3;
Rm = 2.6;
Kt = 7.67*10^-3;
Km = 7.67*10^-3;
Kg = 3.71;
Jm = 3.9*10^-7;
g = 9.81;

a = M*r^2*Rm + Kg^2*Jm*Rm;
b = Kg^2*Kt*Km;
c = Kg*Kt*r;
d = M + m/4;
e = M*c;
f = M*b;

a12 = 1;

a22 = -f/d/a;
a23 = -3/4*m*g/d;
b2 = e/d/a;

a34 = 1;

a42 = f/(4/3*Lp)/d/a;
a43 = 3/4*g/Lp + 3/4*m*g/d/(4/3*Lp);
b4 = -e/(4/3*Lp)/d/a;
```

```
A = [0 a12   0   0;
     0 a22 a23   0;
     0   0   0 a34;
     0 a42 a43   0];
B = [0; b2; 0; b4];
C = [1 0 0 0;
     0 0 1 0];
D = 0;
```

evals_ref = [-2+10i -2-10i -1.6+1.3i -1.6-1.3i]; poly_ref = [1 7.2 121.05 349.8 442]; K = place(A,B,evals_ref); Ak = A-B*K; Bk = B*K;

```
%K_lab = [-12.9796 -14.723 -47.8456 -6.5363];
```

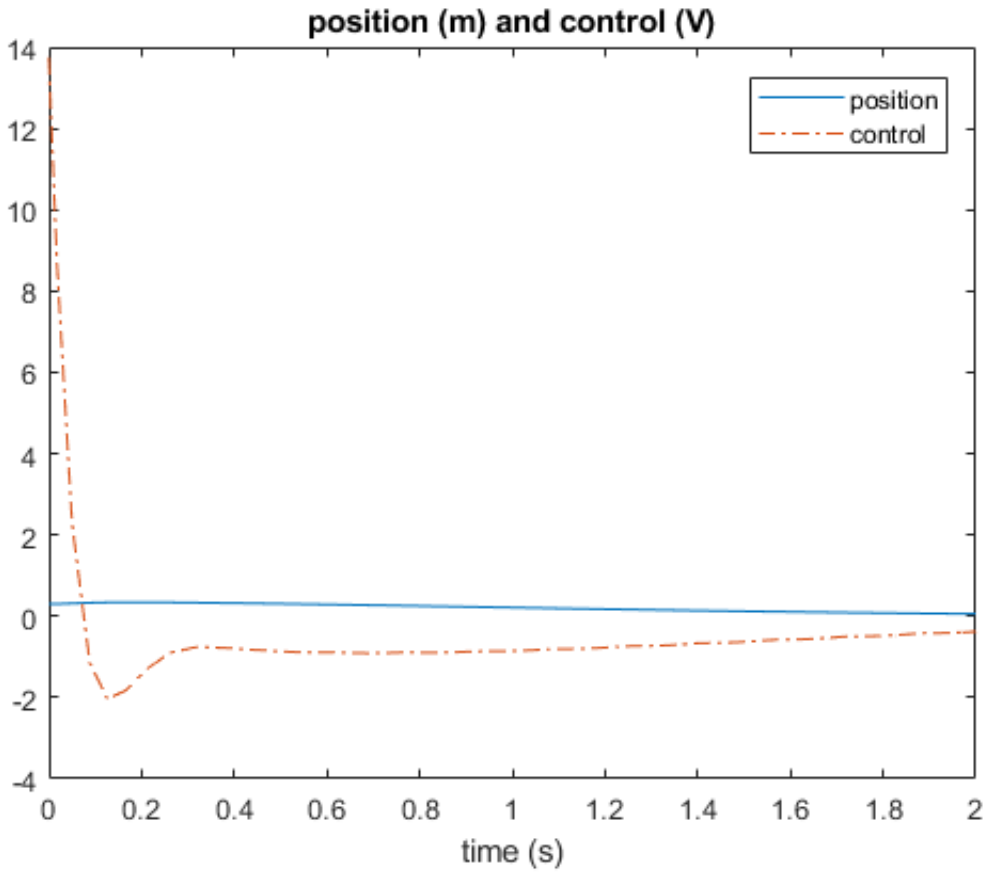
P = [-10+15j -10-15j -12+17j -12-17j]; % eig of (A-LC) = eig of (A' - C'*L') l = place(A',C',P); L = l'; Cl = L*C;

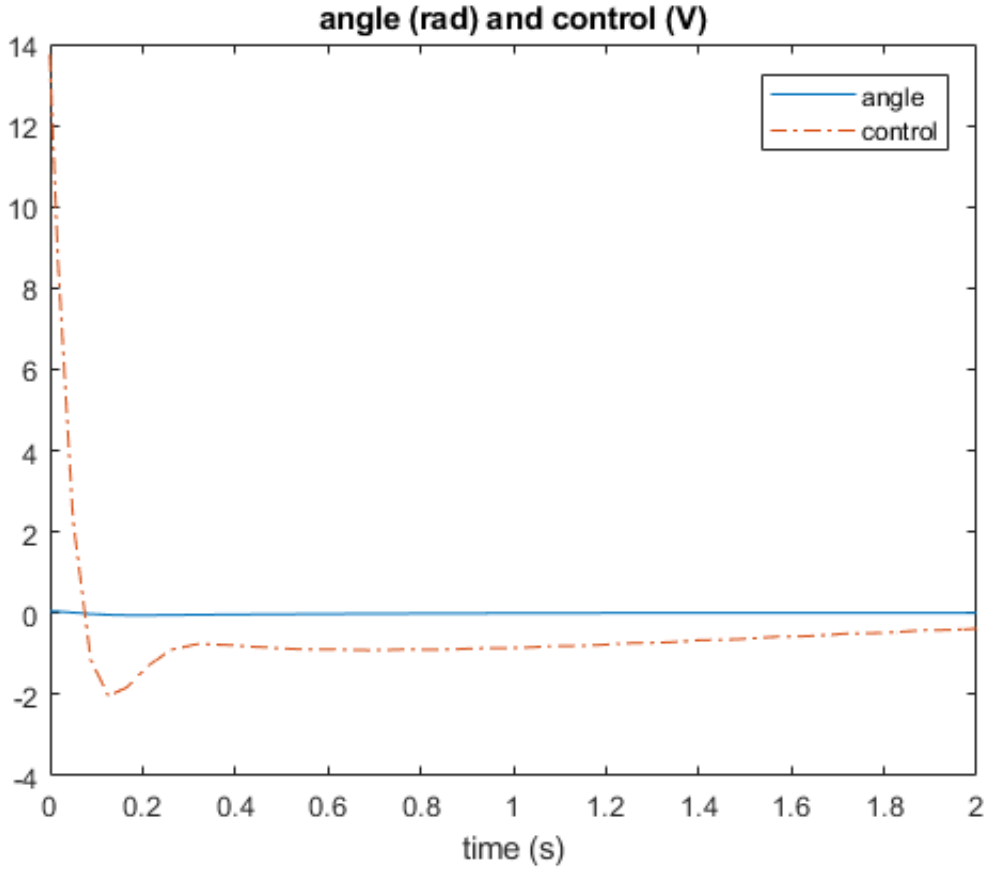
3.1

```
%dim Q = 4x4 because x is 4x1. dim R = 1x1 because u is 1x1
ref = [0 0 0 0];
x0 = 0.3;
a0 = 0.05;
ic = [0.3 0 0.05 0];
q2 = 0;
q4 = 0;
disp('case1: nominal');
q1 = 1;
q3 = 1;
r = 1;
q1_n = q1/x0^2;
q3_n = q3/a0^2;
r_n = r/6^2;

Q = [q1_n 0 0    0;
     0    0 0    0;
     0    0 q3_n 0;
     0    0 0    0];
R = r_n;

[K,S,E] = lqr(A,B,Q,R);
Ak = A-B*K;
Bk = B*K;
disp(['The K values are;',num2str(K)])
disp(['The eigen values/CL poles are;',num2str(E')])

%%make obsever poles far from CL poles (6 times)
P = 6*E';
l = place(A',C',P);
L = l'
Cl = L*C;

sim('pl6c')

x = x';
y = C*x;
y = y';
r_x_h = r_x_h';
u = K*r_x_h;
u = u';
disp(['max position deviation is:', num2str(max(abs(y(:,1))))])
disp(['max angle deviation is:', num2str(max(abs(y(:,2))))])
disp(['max abs control is:', num2str(max(abs(u)))]);

figure;
plot(t,y(:,1),t,u,'-.');
legend('position','control');
xlabel('time (s)');
title('position (m) and control (V)');
xlim([0 2]);
```

```
figure;
plot(t,y(:,2),t,u,'-.');
legend('angle','control');
xlabel('time (s)');
title('angle (rad) and control (V)');
xlim([0 2]);
```

```
case1: nominal
The K values are;-20     -29.39458     -155.0089      -20.4077
The eigen values/CL poles are;-15.2514-13.5564i          -15.2514+13.5564i         -0.948735-
0.84726i         -0.948735+0.84726i

L =

   1.0e+03 *

    0.1058   -0.0037
    2.0971    0.1145
    1.2833    0.0818
    6.0063    0.4224

max position deviation is:0.34527
max angle deviation is:0.05
max abs control is:13.7504
```





3.2

```
%%case2
disp('case2: q3 = 0.01 << 1');
q1 = 1;
q3 = 0.01;
r = 1;
q1_n = q1/x0^2;
q3_n = q3/a0^2;
r_n = r/6^2;

Q = [q1_n 0 0    0;
     0    0 0    0;
     0    0 q3_n 0;
     0    0 0    0];
R = r_n;
[K,S,E] = lqr(A,B,Q,R);
Ak = A-B*K;
Bk = B*K;
disp(['The K values are;',num2str(K)])
disp(['The eigen values/CL poles are;',num2str(E')])

sim('pl6c')

x = x';
y = C*x;
y = y';
r_x_h = r_x_h';
u = K*r_x_h;
```

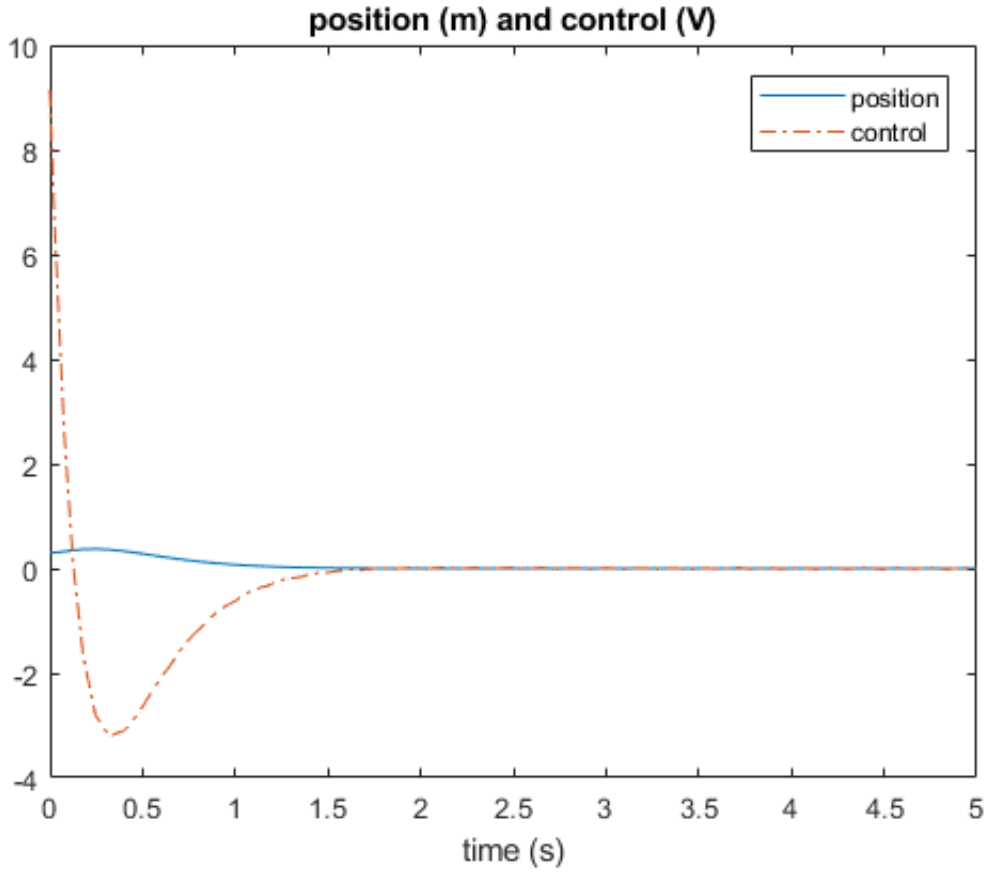
```
u = u';

disp(['max position deviation is:', num2str(max(abs(y(:,1))))])
disp(['max angle deviation is:', num2str(max(abs(y(:,2))))])
disp(['max abs control is:', num2str(max(abs(u)))]);
%small q3 gives bigger change in x and theta but smaller control

figure;
plot(t,y(:,1),t,u,'-.');
legend('position','control');
xlabel('time (s)');
title('position (m) and control (V)');

figure;
plot(t,y(:,2),t,u,'-.');
legend('angle','control');
xlabel('time (s)');
title('angle (rad) and control (V)');

%%case3
disp('case3: q3 = 100 >> 1');
q1 = 1;
q3 = 100;
r = 1;
q1_n = q1/x0^2;
q3_n = q3/a0^2;
r_n = r/6^2;

Q = [q1_n 0 0    0;
     0    0 0    0;
     0    0 q3_n 0;
     0    0 0    0];
R = r_n;
[K,S,E] = lqr(A,B,Q,R);
Ak = A-B*K;
Bk = B*K;
disp(['The K values are;',num2str(K)])
disp(['The eigen values/CL poles are;',num2str(E')])

sim('pl6c')

x = x';
y = C*x;
y = y';
r_x_h = r_x_h';
u = K*r_x_h;
u = u';

disp(['max position deviation is:', num2str(max(abs(y(:,1))))])
disp(['max angle deviation is:', num2str(max(abs(y(:,2))))])
disp(['max abs control is:', num2str(max(abs(u)))]);
%big q3 gives smaller change in x and same in theta but bigger control

figure;
plot(t,y(:,1),t,u,'-.');
legend('position','control');
xlabel('time (s)');
```

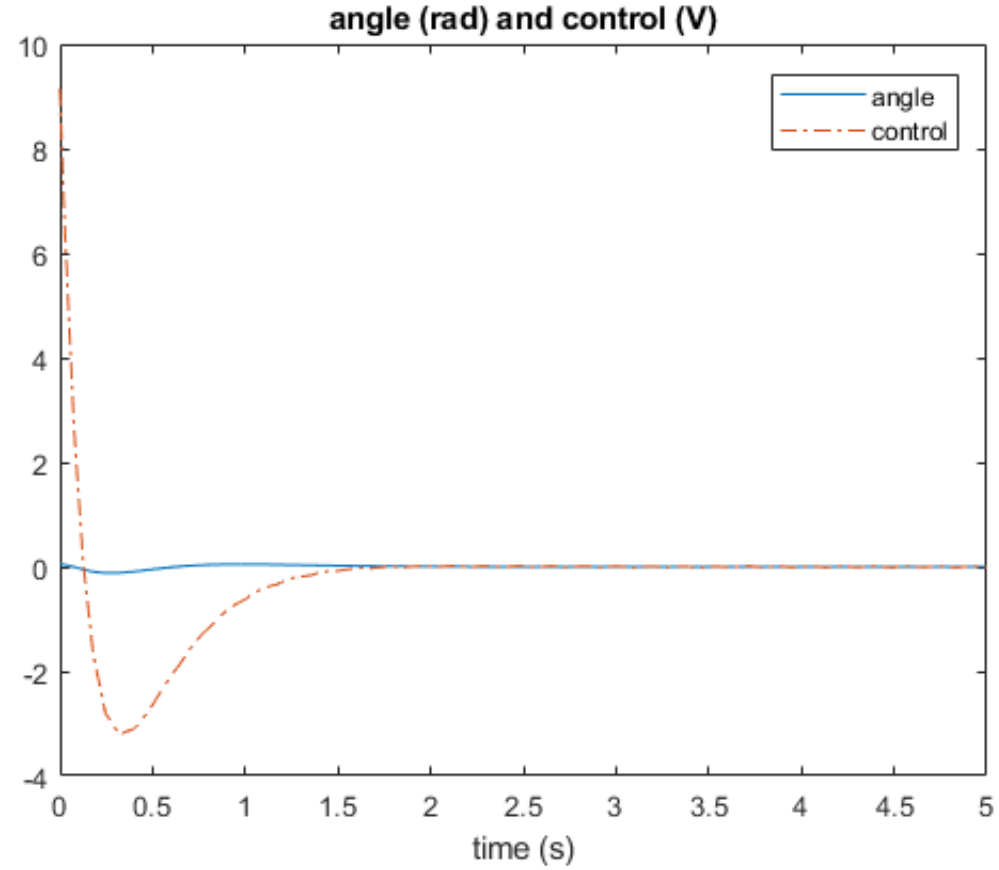
```
title('position (m) and control (V)');

figure;
plot(t,y(:,2),t,u,'-.');
legend('angle','control');
xlabel('time (s)');
title('angle (rad) and control (V)');

%%case4
disp('case4: r = 0.01 << 1');
q1 = 1;
q3 = 1;
r = 0.01;
q1_n = q1/x0^2;
q3_n = q3/a0^2;
r_n = r/6^2;

Q = [q1_n 0 0    0;
     0    0 0    0;
     0    0 q3_n 0;
     0    0 0    0];
R = r_n;
[K,S,E] = lqr(A,B,Q,R);
Ak = A-B*K;
Bk = B*K;
disp(['The K values are;',num2str(K)])
disp(['The eigen values/CL poles are;',num2str(E')])

sim('pl6c')

x = x';
y = C*x;
y = y';
r_x_h = r_x_h';
u = K*r_x_h;
u = u';

disp(['max position deviation is:', num2str(max(abs(y(:,1))))])
disp(['max angle deviation is:', num2str(max(abs(y(:,2))))])
disp(['max abs control is:', num2str(max(abs(u)))]);
%small r gives slightly smaller change in x and slightly bigger change in theta but bigger co
ntrol

figure;
plot(t,y(:,1),t,u,'-.');
legend('position','control');
xlabel('time (s)');
title('position (m) and control (V)');

figure;
plot(t,y(:,2),t,u,'-.');
legend('angle','control');
xlabel('time (s)');
title('angle (rad) and control (V)');

%%case5
disp('case5: r = 100 >> 1');
```

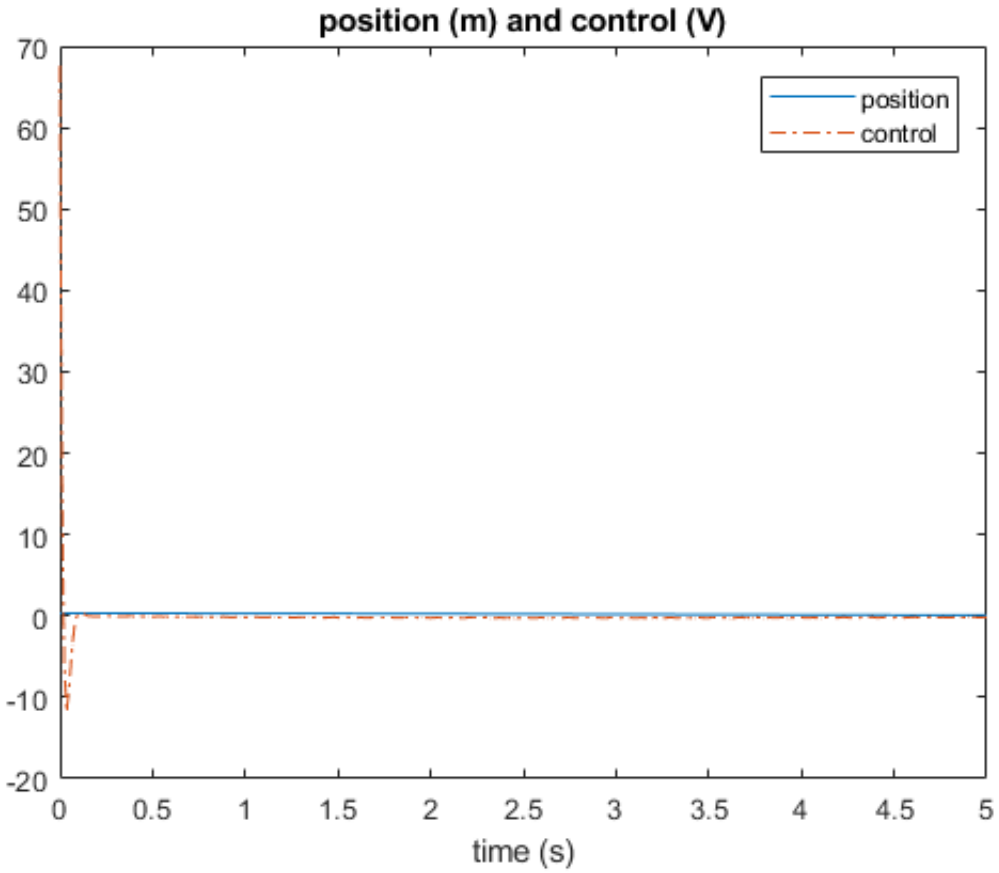
```
q1 = 1;
q3 = 1;
r = 100;
q1_n = q1/x0^2;
q3_n = q3/a0^2;
r_n = r/6^2;

Q = [q1_n 0 0    0;
     0    0 0    0;
     0    0 q3_n 0;
     0    0 0    0];
R = r_n;
[K,S,E] = lqr(A,B,Q,R);
Ak = A-B*K;
Bk = B*K;
disp(['The K values are;',num2str(K)])
disp(['The eigen values/CL poles are;',num2str(E')])

sim('pl6c')

x = x';
y = C*x;
y = y';
r_x_h = r_x_h';
u = K*r_x_h;
u = u';

disp(['max position deviation is:', num2str(max(abs(y(:,1))))])
disp(['max angle deviation is:', num2str(max(abs(y(:,2))))])
disp(['max abs control is:', num2str(max(abs(u)))]);
%big r gives slightly smaller change in x and same theta but smaller control

figure;
plot(t,y(:,1),t,u,'-.');
legend('position','control');
xlabel('time (s)');
title('position (m) and control (V)');

figure;
plot(t,y(:,2),t,u,'-.');
legend('angle','control');
xlabel('time (s)');
title('angle (rad) and control (V)');
```

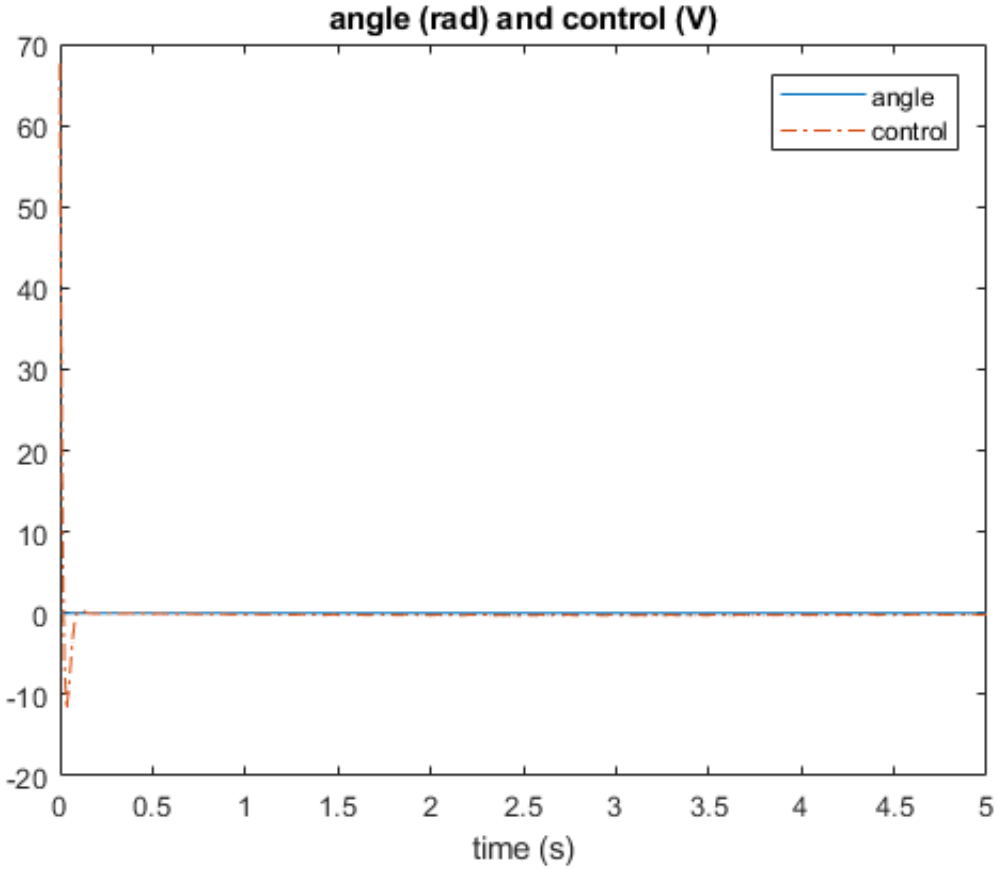
```
case2: q3 = 0.01 << 1
The K values are;-20     -20.1536     -62.9958     -12.8567
The eigen values/CL poles are;-7.2972-3.2902i          -7.2972+3.2902i          -2.9239-1.401
6i          -2.9239+1.4016i
max position deviation is:0.3718
max angle deviation is:0.11963
max abs control is:9.1498
case3: q3 = 100 >> 1
The K values are;-20     -75.269428     -1231.8874     -57.932371
The eigen values/CL poles are;-45.6609-45.121i           -45.6609+45.121i        -0.287533-0.
284266i        -0.287533+0.284266i
```

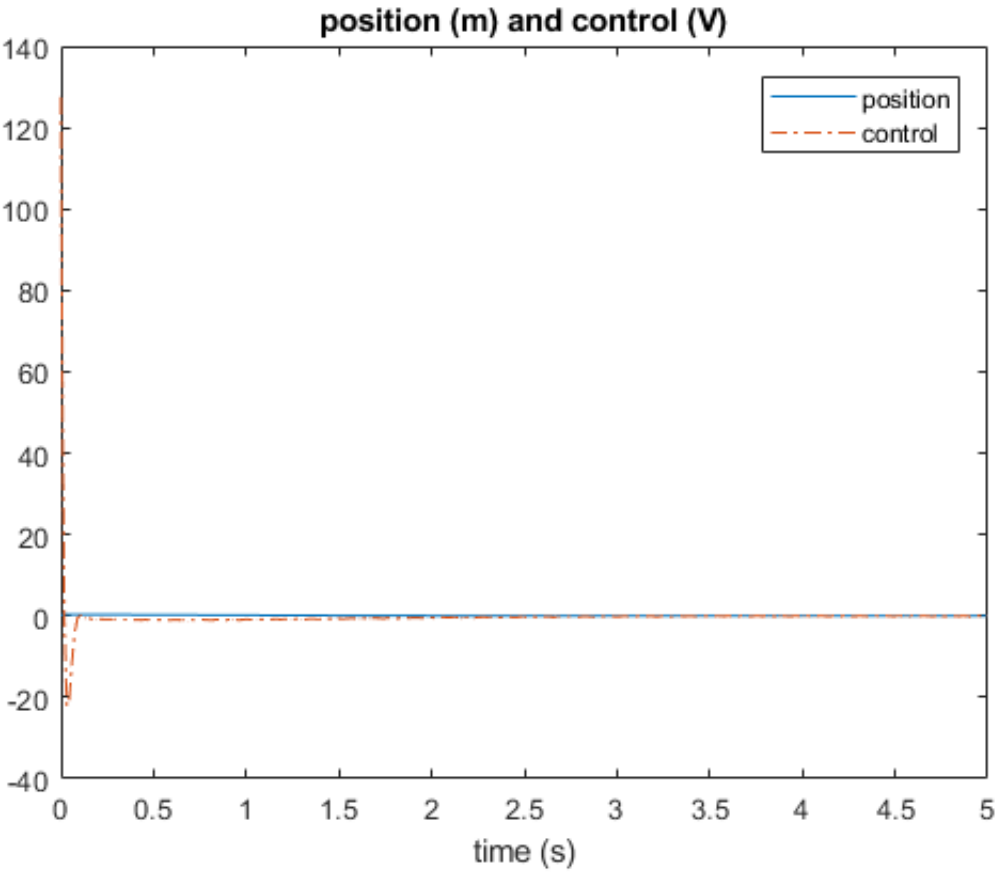
```
max position deviation is:0.32615
max angle deviation is:0.05
max abs control is:67.5944
case4: r = 0.01 << 1
The K values are;-200      -238.4112     -1349.2888     -130.17026
The eigen values/CL poles are;-45.7202-45.1824i          -45.7202+45.1824i        -0.935536-0
.869056i        -0.935536+0.869056i
max position deviation is:0.34633
max angle deviation is:0.054905
max abs control is:127.4644
case5: r = 100 >> 1
The K values are;-2      -10.208     -39.1463     -7.63995
The eigen values/CL poles are;-7.3602-2.851i           -7.3602+2.851i               -2.3926+0
i              -0.45194+0i
max position deviation is:0.34989
max angle deviation is:0.05
max abs control is:2.5573
```

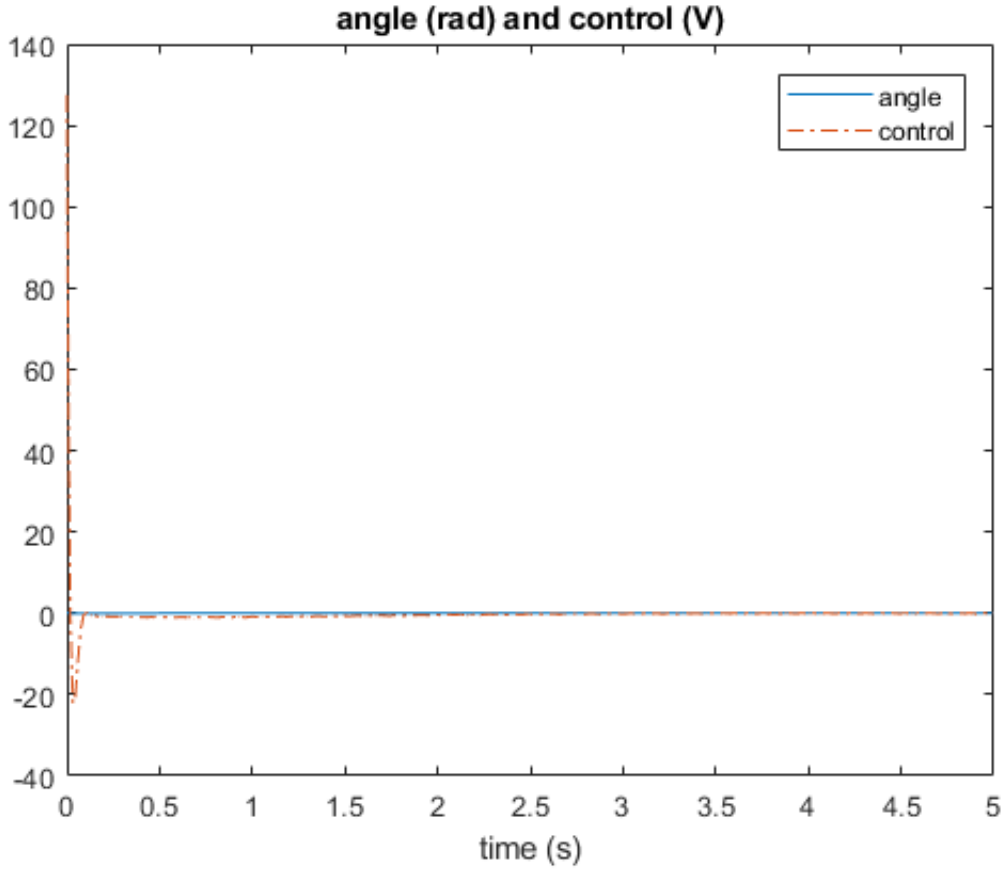


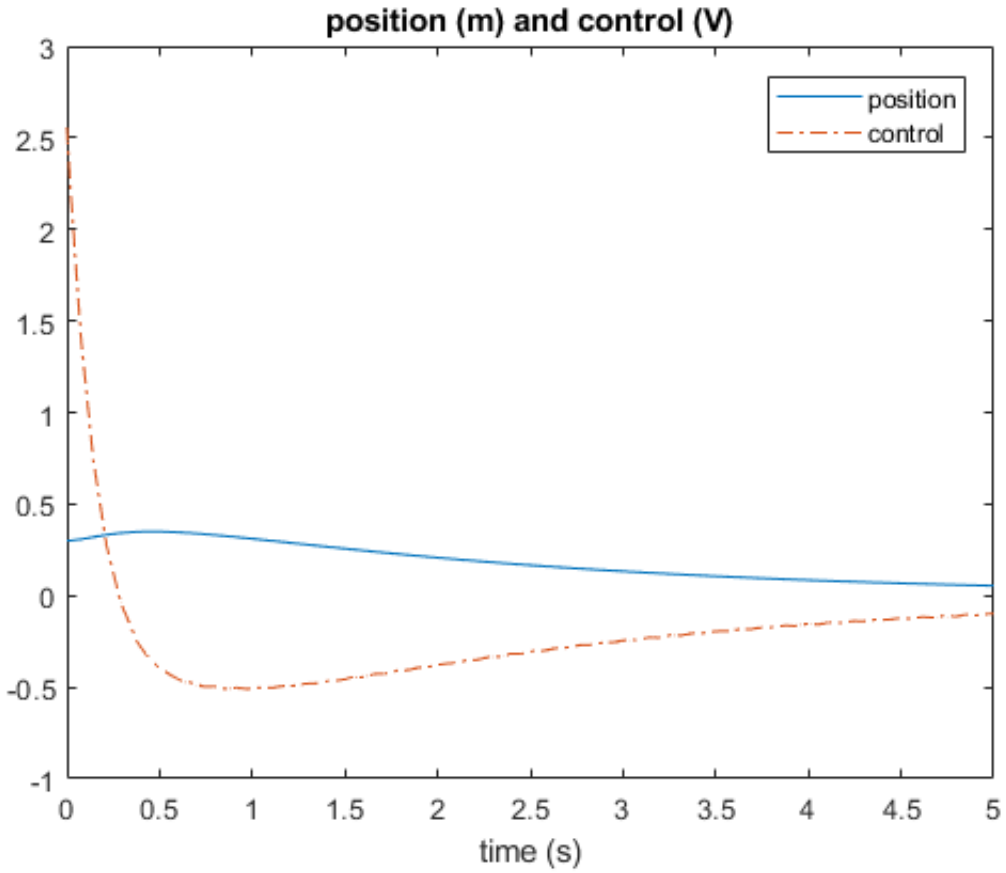

angle (rad) and control (V)
angle
control
time (s)

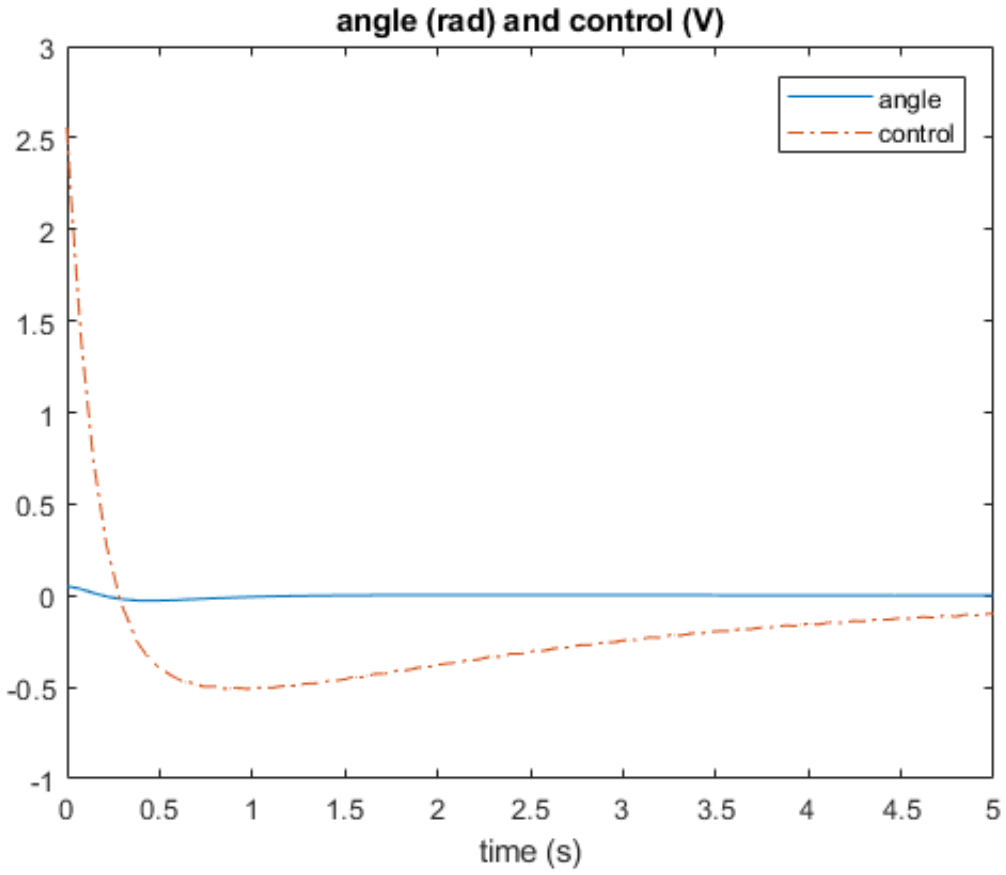

position (m) and control (V)
position
control
time (s)


angle (rad) and control (V)
angle
control
70
60
50
40
30
20
10
0
-10
-20
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
time (s)


position (m) and control (V)
position
control
140
120
100
80
60
40
20
0
-20
-40
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
time (s)


angle (rad) and control (V)
angle
control
140
120
100
80
60
40
20
0
-20
-40
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
time (s)


position (m) and control (V)
position
control
3
2.5
2
1.5
1
0.5
0
-0.5
-1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
time (s)



3.3

```
%position will first increase before converging to zero shows that the cart
%is moving to swing the angle closer to 0
```

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