MATLAB Code

Q1

```
%part a
A = [0,1,0; 0,0,1; 1,5,7]
B= [1;0;0]
C = [0 1 3]
% C= A*A*B
E = eig(A)

%part b
W_c= [1 ,0,0; 0,0,1;0,1,7]
determinant = det(W_c)


% part c
time = linspace(0,2,1000);
xt = []
x0  = [0;1;0]
for j = 1: size(time,2)
    xt(:,end+1) = expm(A*time(j))*x0;
end
y = C*xt;
figure(1)
% plot(time, xt(1,:))
plot(time, y)
title('unforced system output')
xlabel('time[s]'); ylabel('System Response')


%part d
p = [ -1+i  -1-i -2];
k = place(A,B,p)


%part e
time = linspace(0,10,1000);
xt = []
for j = 1:size(time,2)
    t= time(j)
    xt(:,j)=expm((A-B*k)*t)*x0;
end
y_forced = C*xt;
figure(2)
plot(time ,y_forced)
title('system output under feedback law')
xlabel('time[s]'); ylabel('System Response’)
```

Q2

```
global a b D miu y K C A B;

A = [0,1,1,0;0,0,0,1;0,1,-3,0;0,2,-3,0]
B = [0;0;1;1]
%original R Q parameters
% R = 10
Q = [1,0,0,0;0,5,0,0;0,0,1,0;0,0,0,5]
R = 10;
% Q = [20,0,0,0;
%      0,5,0,0;
%      0,0,20,0;
%      0,0,0,5];

E = eig(A);
[K,S,P] = lqr(A,B,Q,R);
time = [0:0.01:200];
x0_all=[[0;0.1;0;0],[0;0.5;0;0],[0; 1.0886;0;0],[0;1.1;0;0]];
xt = [];

%Part d
for j = 1:size(x0_all,2)
   x0 = x0_all(:,j)
   for i = 1:size(time,2)
      t = time(i);
      xt(1:4,i)=expm((A-B*K)*t)*x0;
   end
   figure();
   plot(time,xt)
   title('unforced system output')
   xlabel('time[s]'); ylabel('System Response')
   legend('x' , 'phi','xdot','phi dot')
end


plotting with ode
global A B K
for j = 1:size(x0_all,2)
   [t,xt] = ode45(@SS_Linear,time,x0_all(:,j));
   figure()
   plot(time,xt)
   title('Linear System with LQR feedback control Output')
   xlabel('time[s]'); ylabel('System Response yt')
   legend('x' , 'phi','xdot','phi dot')
end


% part e
global a b D miu y K;
a = 1;
b =1 ;
D =1 ;
```

```
miu=3;
y =2;
for j = 1:size(x0_all,2)
    [t,xt] = ode45(@SS_nonlinear,time,x0_all(:,j));
    figure()
    plot(time,xt);
    legend('x' , 'phi','xdot','phi dot')
    title('Non-Linear System with LQR feedback control Output yt')
    xlabel('time[s]'); ylabel('System Response')
end


%part g
a = 1;
b =1 ;
D =1 ;
C = [39.3701 0 0 0];
miu=3;
y =2;

v = 0.508*square(1/100*2*pi*time);
x0 = [0;0;0;0]
[t,xt] = ode45(@SS_Nonlinear_tracking,time,x0);

xt= xt*39.3701

figure()
plot(time,xt)
title('state vs time')
xlabel('time[s]')
ylabel('System Responses')


figure()
plot(time,xt(:,1));hold on;
plot(time,v)
legend('Actual Output','Desired Ouput' )
xlabel('time[s]')
ylabel('System Response[m]')


function xdot = SS_Linear(t,x)
global A B K
u = K*x
xdot = A*x - B*u;
end


function xdot = SS_Linear(t,x)
global A B K
v = square(1/100*2*pi*t)
u =v-K*x;
xdot = A*x - B*u;
end
```

```
function dqdt = SS(t,x)
global a b D miu y K;
F = -K*x;
dqdt= [x(3);x(4);a/(y*a-b^2*cos(x(2)^2))*(F+b/a*D*sin(x(2)*cos(x(2)))-b*x(4)^2*sin(x(2))-miu*x(3));
    (b*cos(x(2)))/(y*a-b^2*cos(x(2)^2))*(F+b/a*D*sin(x(2)*cos(x(2)))-b*x(4)^2*sin(x(2))-miu*x(3))
+D*sin(x(2))/a];
end


function dqdt = SS(t,x)
global a b D miu y K A B C;
yd = 0.508*square(1/100*2*pi*t);
v = -inv(C*inv(A-B*K)*B)*yd;
F = v-K*x;

dqdt= [x(3);x(4);a/(y*a-b^2*cos(x(2)^2))*(F+b/a*D*sin(x(2)*cos(x(2)))-b*x(4)^2*sin(x(2))-miu*x(3));
    (b*cos(x(2)))/(y*a-b^2*cos(x(2)^2))*(F+b/a*D*sin(x(2)*cos(x(2)))-b*x(4)^2*sin(x(2))-miu*x(3))
+D*sin(x(2))/a];
end
```