```
% Cart and Pendulum
% main calling routine

X = zeros(4,1);
dX = zeros(4,1);
Ref = 1;
dt = 0.01;
t = 0;

m1 = 1;
m2 = 4;
R = 1;
Ts = 8; MOS = 0.05;
[Kx, Kr] = ObtainCartFeedback(m1,m2,R,Ts,MOS);
% Kx = [-1.0714, -78.5964, -2.5230, -12.5230];
% Kr = -1.0714;

pause;
U = 0;
y = [];
dim = [0.3 0.6 0.2 0.15];
an = annotation('textbox', dim, 'String', '', 'FitBoxToText',
'on');
while(t < Ts*2)
 U = Kr*Ref - Kx*X;
 dX = CartDynamics(X, U, m1, m2, R);
 X = X + dX * dt;
 t = t + dt;

 CartDisplay(X, Ref);
 y = [y ; X(1), X(2), Ref];

 str = sprintf('Time = %.2f s', t);
 an.String = str;
 drawnow;
end

t = linspace(0,Ts*10,length(y));
plot(t,y);
xlabel('Time (s)'); title('Nonlinear System Model: Step
Response');
```

```
function [Kx, Kr] = ObtainCartFeedback(m1,m2,R, Ts, MOS)

% m1 = 1; m2 = 4; R = 1;
[A,B] = linearizedCartPend(m1,m2,R) %#ok<NOPRT>
sig = getSigForTs(Ts);
[zeta, th, w] = getForOS(MOS,sig); %#ok<ASGLU>
dom_poles = [sig+1j*w, sig-1j*w];
des_poles = [dom_poles, 5*sig, 5*sig-1] %#ok<NOPRT>

C1 = [1 0 0 0]; % Position of cart
C2 = [0 1 0 0]; % Angle of bar
C = C1;
% olPoles = flip(eig(A));

[Kx,Kr] = placePoles(A,B,C,des_poles) %#ok<NOPRT>

G1 = ss(A-B*Kx, B*Kr, C1, 0);
G2 = ss(A-B*Kx, B*Kr, C2, 0);
G = G1;
U = ss(A-B*Kx, B*Kr, -Kx, Kr);

step(G);
hold on;
step(G2);
step(U);
legend('x(t)','\theta(t)','F(t)');
xlabel('Time (s)'); title('Linearized System Model: Step
Response');
hold off;

end
```

```
function [A,B] = linearizedCartPend(m1, m2, R)
g = 9.8;
A = [0 0 1 0; 0 0 0 1; 0 (-m2*g/m1) 0 0; 0 ((m1+m2)*g/m1) 0 0];
B = [0;0;1/m1;-1/(m1*R)];
end

function [sig] = getSigForTs(Ts)
tau = Ts/4;
sig = -1/tau;
end

function [zeta, th, w] = getForOS(desired_OS, sig)

MOS = @(z) exp(-pi * (z./sqrt(1-z.^2)));
E = @(z) abs(MOS(z) - desired_OS);
[zeta,err] = fminsearch(E, 0.5);
th = acosd(zeta);
w = abs(sig)*tand(th);

end
```

```
function [ dX ] = CartDynamics( X, F, m1, m2, R )

%cart dynamics  (Sp21 version)
% X = [x, q, dx, dq]
g = 9.8;

x = X(1); %#ok<NASGU>
q = X(2);
dx = X(3);
dq = X(4);

M = [(m1+m2) (m2*R*cos(q)); (m2*R*cos(q)) (m2*R^2)];
A = [m2*R*dq*dq*sin(q); m2*R*g*sin(q)];
B = [1;0];
d2X = inv(M) * (A + B*F); %#ok<MINV>
dX = [dx; dq; d2X];

end

function [] = CartDisplay(X, Ref)
% Cart Display
% ECE 463 Lecture #7

x = X(1);
q = X(2);
% cart
xc = [-0.2,0.2,0.2,-0.2,-0.2] + x;
yc = [0,0,0.2,0.2,0];
xm = x + sin(q);
ym = 0 + cos(q);
% ball
q = [0:0.1:1]' * 2*pi;
xb = 0.05*cos(q) + xm;
yb = 0.05*sin(q) + ym;
plot([-3,3],[0,0],'b-',xc,yc,'r-',[x,xm],[0,ym]+0.2,'r-',xb,
0.2+yb, 'r-',[Ref, Ref],[-0.1,0.1],'b')
ylim([-0.5,1.5]);
pause(0.01);

end
```