Part 1

Contents

1.a

```
% Given Constants
g   = 9.81;         % gaccel[m/s^2]
mp  = 0.230;        % massofpendulum[kg]
l   = 0.6413;       % lengthofpendulum[m]
r   = l/2;          % radiustoCOMofpendulum[m]
J   = (1/3)*mp*l^2; % inertiaofpendulumrotatingabout1end[kg-m^2]
y   = 0.0024;       % pendulumdamping[N-m*s]
mc  = 0.38;         % massofcart[kg]
c   = 0.90;         % cartdamping[N-s/m]

% Derived Constants
Mhat = mp + mc;
Jhat = J + mp*r^2;
mu = mp^2 * r^2 - Jhat^2 * Mhat^2;

A = [0 0 1 0;
     0 0 0 1;
     0, g/mu, (Jhat*c)/mu, -(y*mp*r)/mu;
     0, -(Mhat*mp*r*g)/mu, -(mp*r*c)/mu, (Mhat*y)/mu]

B = [0; 0; -Jhat/mu; -(mp*r)/mu]

C = [1 0 0 0; 0 1 0 0]

D = [0; 0]
```

```
A =

   1.0e+03 *

         0         0    0.0010         0
         0         0         0    0.0010
         0    2.2782    0.0115   -0.0000
         0   -0.1025   -0.0154    0.0003


B =

         0
         0
  -12.8140
  -17.1268


C =

     1     0     0     0
     0     1     0     0


D =

     0
     0
```

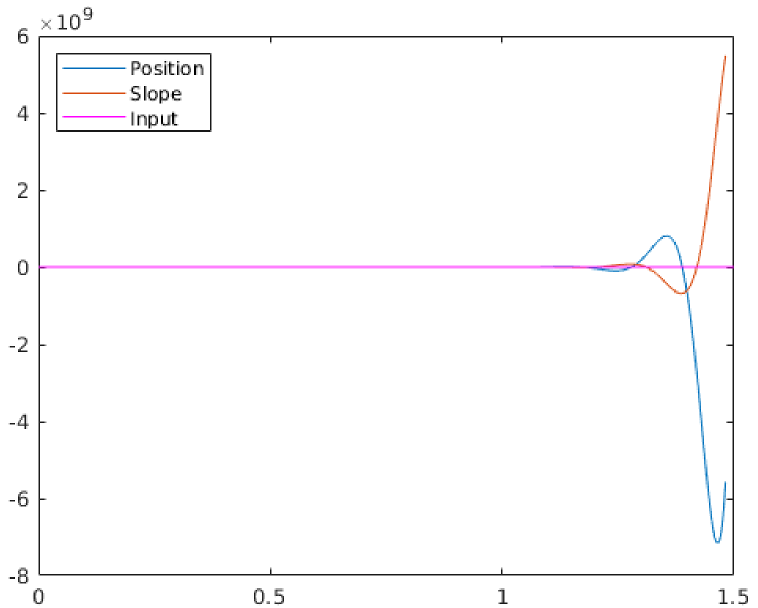
1.b

```
sys = ss(A, B, C, D)
eig(A)
```

```
opt = stepDataOptions('StepAmplitude', 0.1)
[y, t, x] = step(sys, opt);

figure(1); clf;
plot(t, y)
hline = refline(0, 0.1)
hline.Color = 'm'

legend("Position", "Slope", "Input", 'Location', 'Northwest')
saveas(gca, 'ES155Lab2_1b_step.jpg')
```

```
sys =

  A =
            x1       x2       x3       x4
   x1        0        0        1        0
   x2        0        0        0        1
   x3        0     2278    11.53  -0.0411
   x4        0   -102.5   -15.41     0.34

  B =
           u1
   x1       0
   x2       0
   x3  -12.81
   x4  -17.13

  C =
       x1  x2  x3  x4
   y1   1   0   0   0
   y2   0   1   0   0

  D =
       u1
   y1   0
   y2   0

Continuous-time state-space model.


ans =

   0.0000 + 0.0000i
  19.8901 +28.6414i
  19.8901 -28.6414i
 -27.9076 + 0.0000i


opt =

  step with properties:

      InputOffset: 0
    StepAmplitude: 0.1000


hline =

  Line with properties:

              Color: [0 0.4470 0.7410]
          LineStyle: '-'
          LineWidth: 0.5000
             Marker: 'none'
         MarkerSize: 6
    MarkerFaceColor: 'none'
              XData: [0 1.5000]
              YData: [0.1000 0.1000]
              ZData: [1×0 double]

  Use GET to show all properties


hline =

  Line with properties:
```

```
             Color: [1 0 1]
         LineStyle: '-'
         LineWidth: 0.5000
            Marker: 'none'
        MarkerSize: 6
   MarkerFaceColor: 'none'
             XData: [0 1.5000]
             YData: [0.1000 0.1000]
             ZData: [1×0 double]

  Use GET to show all properties
```



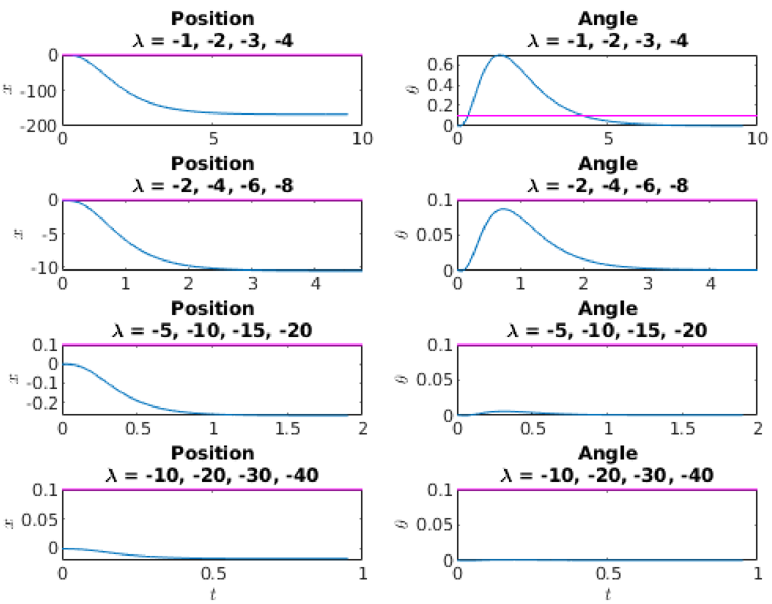
1.c

```
% the smaller poles allow the pendulum to be pushed around before reaching
% an equilibrium, while the large value poles keep the pendulum at the
% equilibrium point theta = 0

figure(2); clf;

plotCount = 1;
pMultipliers = [1, 2, 5, 10]
for i = 1:length(pMultipliers)
    p = [-1, -2, -3, -4];
    p = p.*pMultipliers(i)
    K = place(A, B, p)

    sys = ss(A- B*K, B, C, 0);
    opt = stepDataOptions('StepAmplitude', 0.1);
    [y, t, x] = step(sys, opt);

    titles = ["Position"; "Angle"];
    ylabels = ["$x$", "$\theta$"]
    for j = 1:2
        subplotIdx = plotCount + j -1
        subplot(length(pMultipliers),2, subplotIdx)
        plot(t, y(:,j))
        hline = refline(0, 0.1);
        hline.Color = 'm';
        title({char(titles(j)), ['\lambda = ', num2str(p(1)), ', ', num2str(p(2)), ', ', num2str(p(3)), ', ', num2str(p(4))]})
        ylabel(char(ylabels(j)), 'Interpreter', 'latex')
    end

    plotCount = plotCount + 2;
end
```

```
subplot(length(pMultipliers), 2, plotCount - 2)
xlabel('$t$', 'Interpreter', 'latex')

subplot(length(pMultipliers), 2, plotCount - 1)
xlabel('$t$', 'Interpreter', 'latex')
```

```
pMultipliers =

     1     2     5    10


p =

    -1    -2    -3    -4


K =

   -0.0006  -33.9358    0.5078   -1.6570


ylabels = 

  1×2 string array

    "$x$"    "$\theta$"


subplotIdx =

     1


subplotIdx =

     2


p =

    -2    -4    -6    -8


K =

   -0.0095  -50.6099    0.3358   -2.1122


ylabels = 

  1×2 string array

    "$x$"    "$\theta$"


subplotIdx =

     3


subplotIdx =

     4


p =

    -5   -10   -15   -20


K =

   -0.3719 -119.7142   -0.4862   -3.2488


ylabels = 
```

```
  1×2 string array

    "$x$"    "$\theta$"


subplotIdx =

     5


subplotIdx =

     6


p =

   -10   -20   -30   -40


K =

   -5.9507 -289.5229   -3.2349   -4.1117


ylabels =

  1×2 string array

    "$x$"    "$\theta$"


subplotIdx =

     7


subplotIdx =

     8
```



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