Parameters and Equilibrium Conditions

```
P1 = [2 1 1 1 1 1];

P2 = [2 1 1 1 0.99 1];

P3 = [2 1 0.5 1 1 1];

P4 = [2 1 1 1 0.5 1];

E1 = [0 0 0];

E2 = [0 pi pi];

case1 = num2cell([P1,E1]);

case2 = num2cell([P1,E2]);

case3 = num2cell([P4,E1]);

case4 = num2cell([P4,E2]);

u = 0;

C = [1 0 0 0 0 0];

D = 0;
```

Case 1: *P1, E1*

```
% pull parameters and initial conditions for case 1
[m0, m1, m2, l1, l2, g, ye, thetale, theta2e] = deal(case1{:});

mt = m0 + m1 + m2;

M = [mt, -m1*11*cos(thetale), -m2*12*cos(theta2e);
    -m1*11*cos(thetale), m1*11^2, 0;
    -m2*12*cos(theta2e), 0, m2*12^2];

G = [0,0,0;0,m1*11*g*cos(thetale),0;0,0,m2*12*g*cos(theta2e)];

W = [1 0 0]';

A = [zeros(3), eye(3); M^-1*(-G), zeros(3)]
```

```
A = 6 \times 6
                           1.0000
       0
                0
                        0
                                         0
                                                  0
                                    1.0000
       0
               0
                        0
                             0
                                                  0
       0
               0
                        0
                                 0
                                      0
                                             1.0000
          -0.5000 -0.5000
       0
                                0
                                         0
                                                  0
       0
          -1.5000 -0.5000
                                 0
                                         0
                                                  0
          -0.5000
                                 0
                                         0
                                                  0
                  -1.5000
```

```
B = [0;0;0;M^{-1}*W]
```

```
B = 6×1
0
0
0
0.5000
0.5000
0.5000
```

```
sys = ss(A,B,C,D);
pole(sys)
```

```
ans = 6×1 complex
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 1.4142i
```

```
-0.0000 + 1.0000i
   -0.0000 - 1.0000i
 zero(sys)
 ans = 4 \times 1 complex
    0.0000 + 1.0000i
    0.0000 - 1.0000i
    0.0000 + 1.0000i
    0.0000 - 1.0000i
Case 2: P1, E2
 [m0, m1, m2, 11, 12, g, ye, theta1e, theta2e] = deal(case2{:});
 mt = m0 + m1 + m2;
 M = [mt, -m1*11*cos(theta1e), -m2*12*cos(theta2e);
      -m1*11*cos(theta1e), m1*11^2, 0;
      -m2*12*cos(theta2e), 0, m2*12^2];
 G = [0,0,0;0,m1*11*g*cos(thetale),0;0,0,m2*12*g*cos(theta2e)];
 W = [1 \ 0 \ 0]';
 A = [zeros(3), eye(3); M^-1*(-G), zeros(3)]
 A = 6 \times 6
         0
                  0
                            0
                                1.0000
                                                       0
                                         1.0000
         0
                   0
                            0
                                     0
                                                       0
         0
                            0
                                     0
                                              0
                                                   1.0000
                  0
         0
            -0.5000
                     -0.5000
                                     0
                                                       0
                                              0
         0
              1.5000
                       0.5000
                                     0
                                              0
                                                       0
         0
              0.5000
                       1.5000
                                     0
                                              0
                                                       0
 B = [0;0;0;M^-1*W]
 B = 6 \times 1
         0
         0
          0
     0.5000
    -0.5000
    -0.5000
 sys = ss(A,B,C,D);
 pole(sys)
 ans = 6 \times 1
         0
         0
    -1.4142
    -1.0000
     1.4142
     1.0000
 zero(sys)
 ans = 4 \times 1
    -1.0000
     1.0000
    -1.0000
     1.0000
```

0.0000 - 1.4142i

Case 3: P4, E1

```
[m0, m1, m2, 11, 12, g, ye, theta1e, theta2e] = deal(case3{:});
mt = m0 + m1 + m2;
M = [mt, -m1*11*cos(theta1e), -m2*12*cos(theta2e);
     -m1*11*cos(thetale), m1*11^2, 0;
     -m2*12*cos(theta2e), 0, m2*12^2];
G = [0,0,0;0,m1*11*q*cos(thetale),0;0,0,m2*12*q*cos(theta2e)];
W = [1 \ 0 \ 0]';
A = [zeros(3), eye(3); M^{-1}*(-G), zeros(3)]
A = 6 \times 6
        0
                 0
                          0
                               1.0000
                                                      0
        0
                 0
                          0
                                   0
                                        1.0000
                                                      0
                          0
                                   0
                                                 1.0000
        0
                 0
                                            0
                    -0.5000
        0
           -0.5000
                                   0
                                             0
                                                      0
        0
           -1.5000
                    -0.5000
                                   0
                                             0
                                                      0
           -1.0000
                    -3.0000
                                   0
                                             0
                                                      0
B = [0;0;0;M^-1*W]
B = 6 \times 1
        0
        0
        0
   0.5000
   0.5000
   1.0000
sys = ss(A,B,C,D);
pole(sys)
ans = 6 \times 1 complex
  0.0000 + 0.0000i
  0.0000 + 0.0000i
  -0.0000 + 1.8113i
  -0.0000 - 1.8113i
  0.0000 + 1.1042i
  0.0000 - 1.1042i
zero(sys)
ans = 4 \times 1 complex
  0.0000 + 1.4142i
  0.0000 - 1.4142i
  0.0000 + 1.0000i
  0.0000 - 1.0000i
```

Case 4: P4, E2

```
[m0, m1, m2, l1, l2, g, ye, thetale, theta2e] = deal(case4{:});
mt = m0 + m1 + m2;
M = [mt, -m1*l1*cos(theta1e), -m2*l2*cos(theta2e);
    -m1*l1*cos(theta1e), m1*l1^2, 0;
    -m2*l2*cos(theta2e), 0, m2*l2^2];
G = [0,0,0;0,m1*l1*g*cos(theta1e),0;0,0,m2*l2*g*cos(theta2e)];
W = [1 0 0]';
```

```
A = [zeros(3), eye(3); M^{-1}*(-G), zeros(3)]
A = 6 \times 6
             0 0 1.0000
0 0 0
0 0
        0
                                       1.0000
        0
                                                        0
        0
                                              0
                                                   1.0000
           -0.5000 -0.5000
1.5000 0.5000
                                   0
        0
                                              0
                                                        0
                                   0
        0
                                              0
                                                        0
        0
           1.0000 3.0000
                                   0
                                              0
                                                        0
B = [0;0;0;M^{-1*W}]
B = 6 \times 1
        0
        0
        0
   0.5000
  -0.5000
   -1.0000
sys = ss(A,B,C,D);
pole(sys)
ans = 6 \times 1
        0
   1.8113
   1.1042
  -1.8113
  -1.1042
zero(sys)
ans = 4 \times 1
   -1.4142
   -1.0000
   1.4142
```

1.0000