

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*l1*cos(thetale), -m2*l2*cos(theta2e);
     -m1*l1*cos(thetale), m1*l1^2, 0;
     -m2*l2*cos(theta2e), 0, m2*l2^2];
G = [0,0,0;0,m1*l1*g*cos(thetale),0;0,0,m2*l2*g*cos(theta2e)];
W = [1 0 0]';
A = [zeros(3), eye(3); M^-1*(-G), zeros(3)]
```

```
A = 6x6
      0      0      0      1.0000      0      0
      0      0      0      0      1.0000      0
      0      0      0      0      0      1.0000
      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 = 6x1
      0
      0
      0
      0.5000
      0.5000
      0.5000
```

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

```
ans = 6x1 complex
      0.0000 + 0.0000i
      0.0000 + 0.0000i
      0.0000 + 1.4142i
```

```

0.0000 - 1.4142i
-0.0000 + 1.0000i
-0.0000 - 1.0000i

```

```
zero(sys)
```

```

ans = 4x1 complex
0.0000 + 1.0000i
0.0000 - 1.0000i
0.0000 + 1.0000i
0.0000 - 1.0000i

```

Case 2: P1, E2

```

[m0, m1, m2, l1, l2, g, ye, thetale, theta2e] = deal(case2{:});
mt = m0 + m1 + m2;
M = [mt, -m1*l1*cos(thetale), -m2*l2*cos(theta2e);
     -m1*l1*cos(thetale), m1*l1^2, 0;
     -m2*l2*cos(theta2e), 0, m2*l2^2];
G = [0,0,0,0,m1*l1*g*cos(thetale),0,0,0,m2*l2*g*cos(theta2e)];
W = [1 0 0]';
A = [zeros(3), eye(3); M^-1*(-G), zeros(3)]

```

```

A = 6x6
      0      0      0      1.0000      0      0
      0      0      0      0      1.0000      0
      0      0      0      0      0      1.0000
      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 = 6x1
      0
      0
      0
      0.5000
     -0.5000
     -0.5000

```

```

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

```

```

ans = 6x1
      0
      0
     -1.4142
     -1.0000
      1.4142
      1.0000

```

```
zero(sys)
```

```

ans = 4x1
     -1.0000
      1.0000
     -1.0000
      1.0000

```

Case 3: P4, E1

```
[m0, m1, m2, l1, l2, g, ye, thetale, theta2e] = deal(case3{:});
mt = m0 + m1 + m2;
M = [mt, -m1*l1*cos(thetale), -m2*l2*cos(theta2e);
     -m1*l1*cos(thetale), m1*l1^2, 0;
     -m2*l2*cos(theta2e), 0, m2*l2^2];
G = [0,0,0;0,m1*l1*g*cos(thetale),0;0,0,m2*l2*g*cos(theta2e)];
W = [1 0 0]';
A = [zeros(3), eye(3); M^-1*(-G), zeros(3)]
```

```
A = 6x6
      0      0      0      1.0000      0      0
      0      0      0      0      1.0000      0
      0      0      0      0      0      1.0000
      0 -0.5000 -0.5000      0      0      0
      0 -1.5000 -0.5000      0      0      0
      0 -1.0000 -3.0000      0      0      0
```

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

```
B = 6x1
      0
      0
      0
      0.5000
      0.5000
      1.0000
```

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

```
ans = 6x1 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 = 4x1 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(thetale), -m2*l2*cos(theta2e);
     -m1*l1*cos(thetale), m1*l1^2, 0;
     -m2*l2*cos(theta2e), 0, m2*l2^2];
G = [0,0,0;0,m1*l1*g*cos(thetale),0;0,0,m2*l2*g*cos(theta2e)];
W = [1 0 0]';
```

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

```
A = 6x6
      0      0      0      1.0000      0      0
      0      0      0      0      1.0000      0
      0      0      0      0      0      1.0000
      0     -0.5000    -0.5000      0      0      0
      0      1.5000      0.5000      0      0      0
      0      1.0000      3.0000      0      0      0
```

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

```
B = 6x1
      0
      0
      0
      0.5000
     -0.5000
     -1.0000
```

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

```
ans = 6x1
      0
      0
      1.8113
      1.1042
     -1.8113
     -1.1042
```

```
zero(sys)
```

```
ans = 4x1
     -1.4142
     -1.0000
      1.4142
      1.0000
```