For the outputs X(t) and theta_2(t) The observer is given as

```
M=1000;
m1=100;
m2=100;
l1=20;
l2=10;
g=9.81;
```

A_f and B_f matrices

```
A_f =[0 1 0 0 0 0;0 0 (-m1*g)/M 0 (-m2*g)/M 0;0 0 0 1 0 0;0 0 -(g/l1)*((m1+M)/M) 0 (-m2*g)/M*l1
```

```
A_f = 6×6
         0    1.0000         0         0         0         0
         0         0   -0.9810         0   -0.9810         0
         0         0         0    1.0000         0         0
         0         0   -0.5396         0  -19.6200         0
         0         0         0         0         0    1.0000
         0         0   -9.8100         0   -1.0791         0
```

```
B_f =[0;1/M;0;1/(M*l1);0;1/(M*l2)]
```

```
B_f = 6×1
10^-3 ×
         0
    1.0000
         0
    0.0500
         0
    0.1000
```

```
eigs(A_f)
```

```
ans = 6×1 complex
  -0.0000 + 3.8322i
  -0.0000 - 3.8322i
  -3.6148 + 0.0000i
   3.6148 + 0.0000i
   0.0000 + 0.0000i
   0.0000 + 0.0000i
```

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

```
C = 2×6
     1     0     0     0     0     0
     0     0     0     0     1     0
```

```
D = [0;0]
```

```
D = 2×1
     0
     0
```

```
plant = ss(A_f,B_f,C,D);
Plant_poles = pole(plant);
```

Controllability Matrix and rank condition

```
Co = ctrb(plant);
rank_Co = rank(Co);
```

Initial conditions

```
I = [0;1;1;0;1;0]
```

```
I = 6×1
     0
     1
     1
     0
     1
     0
```

Luenberger Observer Design

```
%Luen_SYS = ss(A_f-L*C,B_f,C,D)
%step(Luen_SYS)
```

Luenberger Observer Design

Controllability Check - Rank condition of the observability matrix satisfies. Hence Observable

```
C_Lo = ctrb(A_f',C')
```

```
C_Lo = 6×12
    1.0000         0         0         0         0         0         0         0 ···
         0         0    1.0000         0         0         0         0         0
         0         0         0         0   -0.9810   -9.8100         0         0
         0         0         0         0         0         0   -0.9810   -9.8100
         0    1.0000         0         0   -0.9810   -1.0791         0         0
         0         0         0    1.0000         0         0   -0.9810   -1.0791
```

```
rak_ctrb1 = rank(C_Lo)
```

```
rak_ctrb1 = 6
```

```
Ob_Lo = obsv(A_f,C)
```

```
Ob_Lo = 12×6
    1.0000         0         0         0         0         0
         0         0         0         0    1.0000         0
         0    1.0000         0         0         0         0
```

```
         0         0         0         0         0    1.0000
         0         0   -0.9810         0   -0.9810         0
         0         0   -9.8100         0   -1.0791         0
         0         0         0   -0.9810         0   -0.9810
         0         0         0   -9.8100         0   -1.0791
         0         0   10.1529         0   20.3058         0
         0         0   15.8790         0  193.6367         0
    ⋮
```

```
rank_Obsv1 = rank(Ob_Lo)
```

```
rank_Obsv1 = 6
```

```
pole(Plant_LQR)
```

```
ans = 6×1 complex
 -14.5859 +13.6057i
 -14.5859 -13.6057i
  -2.1921 + 3.6421i
  -2.1921 - 3.6421i
  -5.5397 + 0.0000i
  -3.6311 + 0.0000i
```

```
Poles_L_Obs = [-28;-30;-10;-6;-2;-4]
```

```
Poles_L_Obs = 6×1
   -28
   -30
   -10
    -6
    -2
    -4
```

```
L = place(A_f',C',Poles_L_Obs)'
```

```
L = 6×2
   34.2743    0.8932
  174.7915   36.8658
  -37.6817 -208.5662
  -47.2669 -228.2706
    1.2047   45.7257
   56.7906  537.4500
```

```
Luen_SYS = ss(A_f-L*C,B_f,C,D)
```

```
Luen_SYS =

  A =
           x1       x2       x3       x4       x5       x6
   x1   -34.27        1        0        0  -0.8932        0
   x2   -174.8        0   -0.981        0   -37.85        0
   x3    37.68        0        0        1    208.6        0
```

```
  x4    47.27        0  -0.5396        0    208.7        0
  x5   -1.205        0        0        0   -45.73        1
  x6   -56.79        0    -9.81        0   -538.5        0

B =
         u1
 x1       0
 x2   0.001
 x3       0
 x4   5e-05
 x5       0
 x6  0.0001

C =
     x1  x2  x3  x4  x5  x6
 y1   1   0   0   0   0   0
 y2   0   0   0   0   1   0

D =
     u1
 y1   0
 y2   0

Continuous-time state-space model.
```

```
step(Luen_SYS)
```