Quiz Chapter 8.5-8.7 and 8.9

Dynamics of Open Chains

```
addpath('C:\Users\Lenovo\Documents\MATLAB\Modern Robotics\mr')
```

Q1 - UR5 Mass Matrix

```
M01 = [1, 0, 0, 0; 0, 1, 0, 0; 0, 0, 1, 0.089159; 0, 0, 0, 1];
M12 = [0, 0, 1, 0.28; 0, 1, 0, 0.13585; -1, 0, 0, 0; 0, 0, 0, 1];
M23 = [1, 0, 0, 0; 0, 1, 0, -0.1197; 0, 0, 1, 0.395; 0, 0, 0, 1];
M34 = [0, 0, 1, 0; 0, 1, 0, 0; -1, 0, 0, 0.14225; 0, 0, 0, 1];
M45 = [1, 0, 0, 0; 0, 1, 0, 0.093; 0, 0, 1, 0; 0, 0, 0, 1];
M56 = [1, 0, 0, 0; 0, 1, 0, 0; 0, 0, 1, 0.09465; 0, 0, 0, 1];
M67 = [1, 0, 0, 0; 0, 0, 1, 0.0823; 0, -1, 0, 0; 0, 0, 0, 1];
G1 = diag([0.010267495893, 0.010267495893,  0.00666, 3.7, 3.7, 3.7]);
G2 = diag([0.22689067591, 0.22689067591, 0.0151074, 8.393, 8.393, 8.393]);
G3 = diag([0.049443313556, 0.049443313556, 0.004095, 2.275, 2.275, 2.275]);
G4 = diag([0.111172755531, 0.111172755531, 0.21942, 1.219, 1.219, 1.219]);
G5 = diag([0.111172755531, 0.111172755531, 0.21942, 1.219, 1.219, 1.219]);
G6 = diag([0.0171364731454, 0.0171364731454, 0.033822, 0.1879, 0.1879, 0.1879]);
Glist = cat(3, G1, G2, G3, G4, G5, G6);
Mlist = cat(3, M01, M12, M23, M34, M45, M56, M67);
Slist = [0,          0,          0,          0,          0,          0;
         0,          1,          1,          1,          0,          1;
         1,          0,          0,          0,         -1,          0;
         0, -0.089159, -0.089159, -0.089159, -0.10915, 0.005491;
         0,          0,          0,          0,  0.81725,          0;
         0,          0,      0.425,    0.81725,          0,  0.81725];
thetalist = [0; pi/6; pi/4; pi/3; pi/2; (2*pi)/3]
```

```
thetalist = 6×1
         0
    0.5236
    0.7854
    1.0472
    1.5708
    2.0944
```

```
M = MassMatrix(thetalist, Mlist, Glist, Slist)
```

```
M = 6×6
    2.1978    0.2723    0.0680   -0.0065    0.1702   -0.0121
    0.2723    3.5537    1.3104    0.2403   -0.0072    0.0000
    0.0680    1.3104    0.8372    0.2476   -0.0072    0.0000
   -0.0065    0.2403    0.2476    0.2537   -0.0072    0.0000
    0.1702   -0.0072   -0.0072   -0.0072    0.2407         0
   -0.0121    0.0000    0.0000    0.0000         0    0.0171
```

Q2 - UR5 Vector c of Coriolis and Centripetal terms

```
dthetalist = [0.2; 0.2; 0.2; 0.2; 0.2; 0.2];
```

```
c = VelQuadraticForces(thetalist, dthetalist, Mlist, Glist, Slist)
```

```
c = 6×1
   -0.1174
   -0.0107
    0.0317
   -0.0148
    0.0234
    0.0029
```

Q3 - UR5 The joint forces/torques required to overcome gravity

```
g = [0; 0; -9.81];
grav = GravityForces(thetalist, g, Mlist, Glist, Slist)
```

```
grav = 6×1
    0.0000
  -41.5967
   -3.9359
    0.1234
    0.0000
    0.0000
```

Q4 - UR5 The joint forces and torques required only to create the end-effector force Ftip.

```
Ftip = [0.1; 0.1; 0.1; 0.1; 0.1; 0.1]
```

```
Ftip = 6×1
    0.1000
    0.1000
    0.1000
    0.1000
    0.1000
    0.1000
```

```
JTFtip = EndEffectorForces(thetalist, Ftip, Mlist, Glist, Slist)
```

```
JTFtip = 6×1
   -0.1388
   -0.0772
   -0.1223
   -0.1491
   -0.0254
    0.1000
```

Q5 - UR5 The resulting joint accelerations (Forward Dynamics).

```
taulist = [0.0128; -41.1477; -3.7809; 0.0323; 0.0370; 0.1034];
ddthetalist = ForwardDynamics(thetalist, dthetalist, taulist, g, Ftip, Mlist,
Glist, Slist)
```

```
ddthetalist = 6×1
    0.1000
    0.0999
    0.1002
    0.0999
    0.1002
    0.1019
```