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Equations of Motion -- Derivation

```
clear all; close all; clc

syms l1 l2 t1 t2 t3 m1 m2 dt1 dt2 ddt1 ddt2 g f3x f3y n3z

L(1) = Link('revolute','d', 0, 'a', 0, 'alpha', 0 ,'modified');
L(2) = Link('revolute','d', 0, 'a', l1, 'alpha', 0 ,'modified');
L(3) = Link('revolute','d', 0, 'a', l2, 'alpha', 0 ,'modified');

RR = SerialLink(L, 'name', 'RR-Manipulator');
```

Newton-Euler Formulation

```
th = [t1 t2 0]

T_01 = RR.A([1], th);
T_12 = RR.A([2], th);
T_2T = RR.A([3], th);
T_0T = RR.A([1 2 3], th);
T_0T = simplify(T_0T)

[R_01, P_01] = tr2rt(T_01); R_10 = transpose(R_01);
[R_12, P_12] = tr2rt(T_12); R_21 = transpose(R_12);
[R_2T, P_2T] = tr2rt(T_2T); R_32 = transpose(R_2T);
[R_0T, P_0T] = tr2rt(T_0T);
R_0T = simplify(R_0T)
P_0T = simplify(P_0T)

PC1 = [l1/2; 0 ; 0];
PC2 = [l2/2; 0 ; 0];

IC1 = (1/12) * m1 * l1^2 * [0 0 0; 0 1 0; 0 0 1];
IC2 = (1/12) * m2 * l2^2 * [0 0 0; 0 1 0; 0 0 1];

f3 = [f3x; f3y; 0];
n3 = [0;0;n3z];

w0 = zeros(3,1);
wd0 = zeros(3,1);

v0 = zeros(3,1);
vd0 = [0 ; 0 ; -g];

% Inward Iteration

% i = 0
w1 = R_10 * w0 + dt1*R_01(1:3,3)
wd1 = R_10 * wd0 + R_10 * cross(w0, dt1*R_01(1:3,3)) + ddt1*R_01(1:3,3)

vd1 = R_10 * (cross(wd0, P_01) + cross(w0, cross(w0, P_01))) + vd0
vcd1 = cross(wd1,PC1) + cross(w1,cross(w1,PC1)) + vd1

F1 = m1 * vcd1
N1 = IC1 * wd1 + cross(w1,IC1*w1)

% i = 1
w2 = R_21 * w1 + dt2*R_12(1:3,3)
wd2 = R_21 * wd1 + R_21 * cross(w1, dt2*R_12(1:3,3)) + ddt2*R_12(1:3,3)

vd2 = R_21 * (cross(wd1, P_12) + cross(w1, cross(w1, P_12))) + vd1
vcd2 = cross(wd2,PC2) + cross(w2,cross(w2,PC2)) + vd2

F2 = m2 * vcd2
N2 = IC2 * wd2 + cross(w2,IC2*w2)

% Outward Iteration

% i = 2
f2 = R_2T * f3 + F2;
n2 = N2 + R_2T*n3 + cross(PC2, F2) + cross(P_2T, R_2T*f3);
```

```

f2 = simplify(f2)
n2 = simplify(n2)

% i = 1
f1 = R_12 * f2 + F1;
n1 = N1 + R_12*n2 + cross(PC1, F1) + cross(P_12, R_12*f2);
f1 = simplify(f1)
n1 = simplify(n1)

```

th =

[t1, t2, 0]

```

[cos(t1 + t2), -sin(t1 + t2), 0, l2*cos(t1 + t2) + l1*cos(t1)]
[sin(t1 + t2), cos(t1 + t2), 0, l2*sin(t1 + t2) + l1*sin(t1)]
[      0,      0, 1,      0]
[      0,      0, 0,      1]

```

R_0T =

```

[cos(t1 + t2), -sin(t1 + t2), 0]
[sin(t1 + t2), cos(t1 + t2), 0]
[      0,      0, 1]

```

P_0T =

```

l2*cos(t1 + t2) + l1*cos(t1)
l2*sin(t1 + t2) + l1*sin(t1)
0

```

w1 =

```

0
0
dt1

```

wd1 =

```

0
0
ddt1

```

vd1 =

```

0
0
-g

```

vcd1 =

```

-(dt1^2*l1)/2
(ddt1*l1)/2
-g

```

F1 =

```

-(dt1^2*l1*m1)/2
(ddt1*l1*m1)/2
-g*m1

```

N1 =

```

0
0
(ddt1*l1^2*m1)/12

```

w2 =

```

0
0
dt1 + dt2

```

wd2 =

```

0
0
ddt1 + ddt2

vd2 =

- l1*cos(t2)*dt1^2 + ddt1*l1*sin(t2)
  l1*sin(t2)*dt1^2 + ddt1*l1*cos(t2)
  -g

vcd2 =

ddt1*l1*sin(t2) - (l2*(dt1 + dt2)^2)/2 - dt1^2*l1*cos(t2)
l1*sin(t2)*dt1^2 + (l2*(ddt1 + ddt2))/2 + ddt1*l1*cos(t2)
  -g

F2 =

-m2*((l2*(dt1 + dt2)^2)/2 - ddt1*l1*sin(t2) + dt1^2*l1*cos(t2))
m2*(l1*sin(t2)*dt1^2 + (l2*(ddt1 + ddt2))/2 + ddt1*l1*cos(t2))
  -g*m2

N2 =

0
0
(l2^2*m2*(ddt1 + ddt2))/l2

f2 =

f3x - m2*((l2*(dt1 + dt2)^2)/2 - ddt1*l1*sin(t2) + dt1^2*l1*cos(t2))
f3y + m2*(l1*sin(t2)*dt1^2 + (l2*(ddt1 + ddt2))/2 + ddt1*l1*cos(t2))
  -g*m2

n2 =

0
(g*l2*m2)/2
n3z + f3y*l2 + (ddt1*l2^2*m2)/3 + (ddt2*l2^2*m2)/3 + (dt1^2*l1*l2*m2*sin(t2))/2 + (ddt1*l1*l2*m2*cos(t2))/2

f1 =

cos(t2)*(f3x - m2*((l2*(dt1 + dt2)^2)/2 - ddt1*l1*sin(t2) + dt1^2*l1*cos(t2))) - sin(t2)*(f3y + m2*(l1*sin(t2)*dt1^2 + (l2*(ddt1 + ddt2))/2 + ddt1*l1*cos(t2))) - (d
sin(t2)*(f3x - m2*((l2*(dt1 + dt2)^2)/2 - ddt1*l1*sin(t2) + dt1^2*l1*cos(t2))) + cos(t2)*(f3y + m2*(l1*sin(t2)*dt1^2 + (l2*(ddt1 + ddt2))/2 + ddt1*l1*cos(t2))) + (

n1 =

n3z + f3y*l2 + f3y*l1*cos(t2) + f3x*l1*sin(t2) + (ddt1*l1^2*m1)/3 + ddt1*l1^2*m2 + (ddt1*l2^2*m2)/3 + (ddt2*l2^2*m2)/3 - (dt2^2*l1*l2*m2*sin(t2))/2 + ddt1*l1*l2*m2*

```

Design Trajectory

```

clear all; close all; clc

l1 = 0.5;
l2 = 0.5;

L(1) = Link('revolute','d', 0, 'a', 0, 'alpha', 0, 'modified');
L(2) = Link('revolute','d', 0, 'a', l1, 'alpha', 0, 'modified');
L(3) = Link('revolute','d', 0, 'a', l2, 'alpha', 0, 'modified');

RR = SerialLink(L, 'name', 'RR-Manipulator');

g = 0
rho = 1000;
r_outer = 0.1;
r_inner = 0.005;
m1 = rho*l1*pi*(r_outer^2 - r_inner^2);
m2 = rho*l2*pi*(r_outer^2 - r_inner^2);

PC1 = [l1/2; 0; 0];
PC2 = [l2/2; 0; 0];

Ix = 0.5*m1*(r_outer^2 + r_inner^2);
Iy = Ix/2 + (1/12)*m1*l1^2; Iz = Ix/2 + + (1/12)*m2*l2^2;

```

```

IC1 = [Ix 0 0; 0 Iy 0; 0 0 Iz]
IC2 = [Ix 0 0; 0 Iy 0; 0 0 Iz]

f3 = [-10;0;0];
n3 = [0;0;10];

w0 = zeros(3,1);
wd0 = zeros(3,1);

vd0 = [0 ; 0 ; 0];

t1_initial = -acos(0.45/0.5)
t2_initial = 2*acos(0.45/0.5)
t1_final = -acos(0.05/0.5)
t2_final = 2*acos(0.05/0.5)

N = 100;
t1 = linspace(t1_initial, t1_final, N+2)
t2 = linspace(t2_initial, t2_final, N+2)
totalTime = 4;
dt = 4/N;
dt1 = (diff(t1))/dt
dt2 = (diff(t2))/dt
ddt1 = (diff(t1,2))/dt^2
ddt2 = (diff(t2,2))/dt^2

for j=1:N

    th = [t1(j) t2(j) 0];

    T_01 = RR.A([1], th);
    T_12 = RR.A([2], th);
    T_2T = RR.A([3], th);
    T_0T = RR.A([1 2 3], th);

    [R_01, P_01] = tr2rt(T_01); R_10 = transpose(R_01);
    [R_12, P_12] = tr2rt(T_12); R_21 = transpose(R_12);
    [R_2T, P_2T] = tr2rt(T_2T); R_32 = transpose(R_2T);
    [R_0T, P_0T] = tr2rt(T_0T);

    x(j) = P_0T(1); y(j) = P_0T(2);

    % i = 0
    w1 = R_10 * w0 + dt1(j)*R_01(1:3,3);
    wd1 = R_10 * wd0 + R_10 * cross(w0, dt1(j)*R_01(1:3,3)) + ddt1(j)*R_01(1:3,3);

    vd1 = R_10 * (cross(wd0, P_01) + cross(w0, cross(w0, P_01))) + vd0;
    vcd1 = cross(wd1,PC1) + cross(w1,cross(w1,PC1)) + vd1;

    F1 = m1 * vcd1 ;
    N1 = IC1 * wd1 + cross(w1,IC1*w1);

    % i = 1
    w2 = R_21 * w1 + dt2(j)*R_12(1:3,3);
    wd2 = R_21 * wd1 + R_21 * cross(w1, dt2(j)*R_12(1:3,3)) + ddt2(j)*R_12(1:3,3);

    vd2 = R_21 * (cross(wd1, P_12) + cross(w1, cross(w1, P_12))) + vd1;
    vcd2 = cross(wd2,PC2) + cross(w2,cross(w2,PC2)) + vd2;

    F2 = m2 * vcd2 ;
    N2 = IC2 * wd2 + cross(w2,IC2*w2);

    % i = 2
    f2 = R_2T * f3 + F2;
    n2(:,j) = N2 + R_2T*n3 + cross(PC2, F2) + cross(P_2T, R_2T*f3);

    % i = 1
    f1 = R_12 * f2 + F1;
    n1(:,j) = N1 + R_12*n2(:,j) + cross(PC1, F1) + cross(P_12, R_12*f2);
end

time = linspace(0, totalTime, N);

% Plot Trajectory
figure(1)
title('Trajectory Animation')
xlabel('X-Direction (m)')
ylabel('Y-Direction (m)')
h = animatedline;
axis([0 1 -0.5 0.5])
for j=1:N
    addpoints(h,x(j),y(j));
    drawnow
    pause(0.05)
end

```

```

% End Effector Position
figure(2)
plot(time, x);
title('EE Position vs. Time')
ylabel('X and Y Plane (m)')
xlabel('Time (s)')
hold on
plot(time, y);
hold off

% Joint Torque
figure(3)
plot(time, n1);
title('Joint Torque vs. Time')
ylabel('Joint Torque (Nm)')
xlabel('Time (s)')
hold on
plot(time, n2);
legend('Joint 1','Joint 2')

```

G =

0

IC1 =

0.0785	0	0
0	0.3657	0
0	0	0.3657

IC2 =

0.0785	0	0
0	0.3657	0
0	0	0.3657

t1_initial =

-0.4510

t2_initial =

0.9021

t1_final =

-1.4706

t2_final =

2.9413

t1 =

Columns 1 through 7

-0.4510	-0.4611	-0.4712	-0.4813	-0.4914	-0.5015	-0.5116
---------	---------	---------	---------	---------	---------	---------

Columns 8 through 14

-0.5217	-0.5318	-0.5419	-0.5520	-0.5621	-0.5722	-0.5823
---------	---------	---------	---------	---------	---------	---------

Columns 15 through 21

-0.5924	-0.6025	-0.6125	-0.6226	-0.6327	-0.6428	-0.6529
---------	---------	---------	---------	---------	---------	---------

Columns 22 through 28

-0.6630	-0.6731	-0.6832	-0.6933	-0.7034	-0.7135	-0.7236
---------	---------	---------	---------	---------	---------	---------

Columns 29 through 35

-0.7337	-0.7438	-0.7539	-0.7640	-0.7741	-0.7842	-0.7943
---------	---------	---------	---------	---------	---------	---------

Columns 36 through 42

-0.8044	-0.8144	-0.8245	-0.8346	-0.8447	-0.8548	-0.8649
---------	---------	---------	---------	---------	---------	---------

Columns 43 through 49

-0.8750 -0.8851 -0.8952 -0.9053 -0.9154 -0.9255 -0.9356

Columns 50 through 56

-0.9457 -0.9558 -0.9659 -0.9760 -0.9861 -0.9962 -1.0063

Columns 57 through 63

-1.0164 -1.0264 -1.0365 -1.0466 -1.0567 -1.0668 -1.0769

Columns 64 through 70

-1.0870 -1.0971 -1.1072 -1.1173 -1.1274 -1.1375 -1.1476

Columns 71 through 77

-1.1577 -1.1678 -1.1779 -1.1880 -1.1981 -1.2082 -1.2183

Columns 78 through 84

-1.2283 -1.2384 -1.2485 -1.2586 -1.2687 -1.2788 -1.2889

Columns 85 through 91

-1.2990 -1.3091 -1.3192 -1.3293 -1.3394 -1.3495 -1.3596

Columns 92 through 98

-1.3697 -1.3798 -1.3899 -1.4000 -1.4101 -1.4202 -1.4302

Columns 99 through 102

-1.4403 -1.4504 -1.4605 -1.4706

t2 =

Columns 1 through 7

0.9021 0.9222 0.9424 0.9626 0.9828 1.0030 1.0232

Columns 8 through 14

1.0434 1.0636 1.0838 1.1040 1.1241 1.1443 1.1645

Columns 15 through 21

1.1847 1.2049 1.2251 1.2453 1.2655 1.2857 1.3059

Columns 22 through 28

1.3260 1.3462 1.3664 1.3866 1.4068 1.4270 1.4472

Columns 29 through 35

1.4674 1.4876 1.5078 1.5279 1.5481 1.5683 1.5885

Columns 36 through 42

1.6087 1.6289 1.6491 1.6693 1.6895 1.7097 1.7298

Columns 43 through 49

1.7500 1.7702 1.7904 1.8106 1.8308 1.8510 1.8712

Columns 50 through 56

1.8914 1.9116 1.9318 1.9519 1.9721 1.9923 2.0125

Columns 57 through 63

2.0327 2.0529 2.0731 2.0933 2.1135 2.1337 2.1538

Columns 64 through 70

2.1740 2.1942 2.2144 2.2346 2.2548 2.2750 2.2952

Columns 71 through 77

2.3154 2.3356 2.3557 2.3759 2.3961 2.4163 2.4365

Columns 78 through 84

2.4567 2.4769 2.4971 2.5173 2.5375 2.5576 2.5778

2.5980 2.6182 2.6384 2.6586 2.6788 2.6990 2.7192

2.7394 2.7595 2.7797 2.7999 2.8201 2.8403 2.8605

2.8807 2.9009 2.9211 2.9413

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524 -0.2524

-0.2524 -0.2524 -0.2524

0.5048 0.5048 0.5048 0.5048 0.5048 0.5048 0.5048

0.5048 0.5048 0.5048 0.5048 0.5048 0.5048 0.5048

Columns 15 through 21

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 22 through 28

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 29 through 35

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 36 through 42

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 43 through 49

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 50 through 56

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 57 through 63

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 64 through 70

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 71 through 77

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 78 through 84

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 85 through 91

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 92 through 98

0.5048	0.5048	0.5048	0.5048	0.5048	0.5048	0.5048
--------	--------	--------	--------	--------	--------	--------

Columns 99 through 101

0.5048	0.5048	0.5048
--------	--------	--------

ddt1 =

1.0e-12 *

Columns 1 through 7

0	0	0	0	0	0	0
---	---	---	---	---	---	---

Columns 8 through 14

0	0	0	0	0	0	0
---	---	---	---	---	---	---

Columns 15 through 21

0	0	0	0	0	0	0
---	---	---	---	---	---	---

Columns 22 through 28

0	0	0	0	0	0	0.0694
---	---	---	---	---	---	--------

Columns 29 through 35

-0.1388	0.1388	-0.1388	0.1388	-0.1388	0.1388	-0.1388
---------	--------	---------	--------	---------	--------	---------

Columns 36 through 42

0.0694	0	0.0694	-0.1388	0.1388	-0.1388	0.1388
--------	---	--------	---------	--------	---------	--------

Columns 43 through 49

-0.1388	0.1388	-0.1388	0.1388	-0.1388	0.1388	-0.1388
---------	--------	---------	--------	---------	--------	---------

Columns 50 through 56

0.0694	0.0694	-0.1388	0.0694	0.0694	-0.1388	0.1388
--------	--------	---------	--------	--------	---------	--------

Columns 57 through 63

0	-0.1388	0	0.1388	0	-0.1388	0
---	---------	---	--------	---	---------	---

Columns 64 through 70

0.1388	0	-0.1388	0	0.1388	0	-0.2776
--------	---	---------	---	--------	---	---------

Columns 71 through 77

0.2776	0	-0.1388	0.1388	-0.1388	0.1388	0
--------	---	---------	--------	---------	--------	---

Columns 78 through 84

-0.1388	0	0.1388	0	-0.1388	0	0.1388
---------	---	--------	---	---------	---	--------

Columns 85 through 91

0	-0.1388	0	0.1388	0	-0.1388	0
---	---------	---	--------	---	---------	---

Columns 92 through 98

0.1388	0	-0.1388	0	0.1388	0	-0.1388
--------	---	---------	---	--------	---	---------

Columns 99 through 100

0	0.1388
---	--------

ddt2 =

1.0e-12 *

Columns 1 through 7

0	0	0	0	0	0	0
---	---	---	---	---	---	---

Columns 8 through 14

0	0	0	0	0	0	0
---	---	---	---	---	---	---

Columns 15 through 21

0	0	0	0	0	0	0
---	---	---	---	---	---	---

Columns 22 through 28

0	0	0	0	0	0	-0.1388
---	---	---	---	---	---	---------

Columns 29 through 35

0.2776	-0.2776	0.2776	-0.2776	0.2776	-0.2776	0.2776
--------	---------	--------	---------	--------	---------	--------

Columns 36 through 42

-0.1388	0	-0.1388	0.2776	-0.2776	0.2776	-0.2776
---------	---	---------	--------	---------	--------	---------

Columns 43 through 49

0.2776	-0.2776	0.2776	-0.2776	0.2776	-0.2776	0.2776
--------	---------	--------	---------	--------	---------	--------

Columns 50 through 56

-0.1388	-0.1388	0.2776	-0.1388	-0.1388	0.2776	-0.2776
---------	---------	--------	---------	---------	--------	---------

Columns 57 through 63

0	0.2776	0	-0.2776	0	0.2776	0
---	--------	---	---------	---	--------	---

Columns 64 through 70

-0.2776	0	0.2776	0	-0.2776	0	0.5551
---------	---	--------	---	---------	---	--------

Columns 71 through 77

-0.5551	0	0.2776	-0.2776	0.2776	-0.2776	0
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Columns 78 through 84

0.2776	0	-0.2776	0	0.2776	0	-0.2776
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Columns 85 through 91

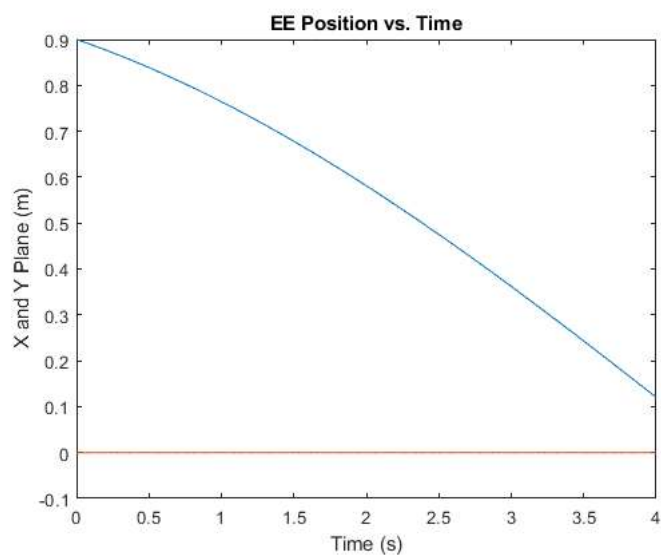
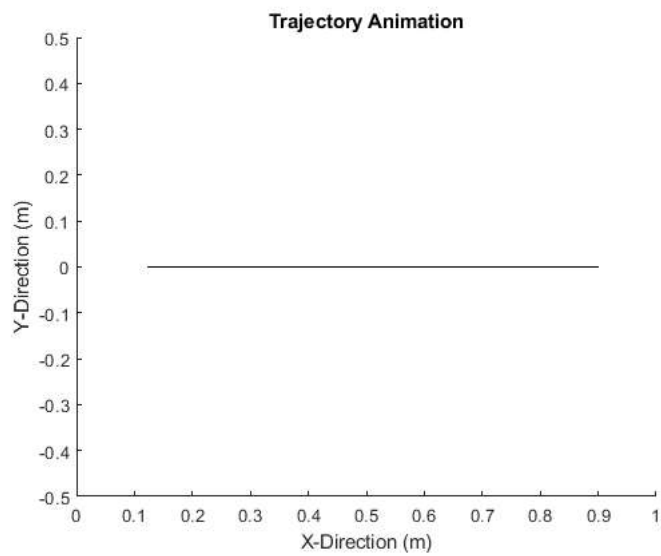
0	0.2776	0	-0.2776	0	0.2776	0
---	--------	---	---------	---	--------	---

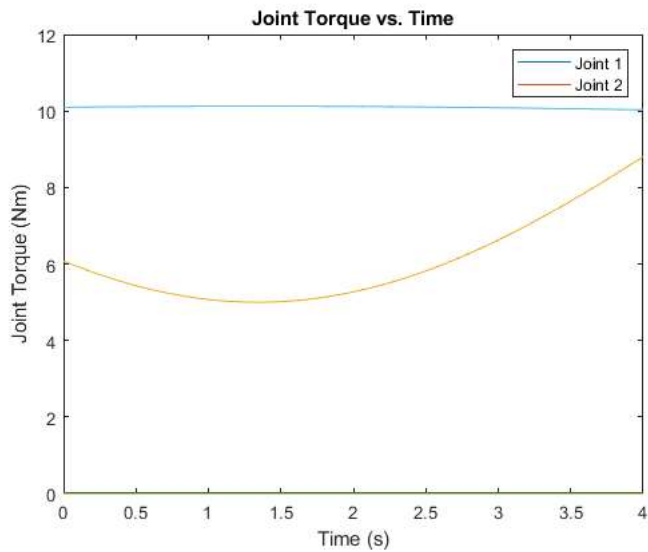
Columns 92 through 98

-0.2776 0 0.2776 0 -0.2776 0 0.2776

Columns 99 through 100

0 -0.2776





Inertia Tensor

```
clear all; close all; clc;

% Body A
h = 0.1; l = 0.1; w = 0.1; r = 0.1; d=0.4;
I_cube = [h^2+l^2 0 0; 0 w^2+h^2 0; 0 0 l^2+h^2];
I_cyl = [(1/12)*(3*r^2+h^2) 0 0; 0 (1/12)*(3*r^2+h^2) 0; 0 0 0.5*r^2];
I_Acm = I_cube - I_cyl;
I_A = I_Acm + ([-d 0 0]*[-d; 0; 0]*eye(3) - [d^2 0 0; 0 0 0; 0 0 0])

% Body B
rB = 0.05; lB = 0.8;
I_B = [0.5*rB^2 0 0; 0 (1/12)*(3*rB^2+lB^2) 0; 0 0 (1/12)*(3*rB^2+lB^2)]

% Body C
I_Ccm = I_Acm;
I_C1 = I_Ccm + ([d 0 0]*[d; 0; 0]*eye(3) - [d^2 0 0; 0 0 0; 0 0 0])
Rotx = [1 0 0; 0 1/2^0.5 1/2^0.5; 0 -1/2^0.5 1/2^0.5];
I_C = Rotx*I_C1*Rotx'

% Total Inertia
syms mA mB mC
I = mA*I_A + mB*I_B + mC*I_C;
I = vpa(I, 4)
```

```
I_A =
    0.0167      0      0
      0    0.1767      0
      0      0   -0.6906

I_B =
    0.0013      0      0
      0    0.0540      0
      0      0    0.0540

I_C1 =
    0.0167      0      0
      0    0.1767      0
      0      0   -0.6906

I_C =
    0.0167      0      0
      0   -0.2569   -0.4336
      0   -0.4336   -0.2569

I =
[0.01667*mA + 0.00125*mB + 0.01667*mC,      0,      0]
[      0, 0.1767*mA + 0.05396*mB - 0.2569*mC,   -0.4336*mC]
```

[0, -0.4336*mC, 0.05396*mB - 0.6906*mA - 0.2569*mC]