```
syms q1 q2 q3 l1 l2 l3 qdot1 qdot2 qdot3 w1 w2 w3 lc1 lc2 lc3 g
assume(q1, 'real')
assume(q2, 'real')
assume(q3, 'real')
assume(lc1, 'real')
assume(lc2, 'real')
assume(lc3, 'real')
assume(l1, 'real')
assume(l2, 'real')
assume(l3, 'real')
l1 = [106];
l2 = [98.7];
l3 = [140.25];


p0=[0;0;0]
```

```
p0 = 3×1
     0
     0
     0
```

```
p1=str2sym('[0 ; 0 ;l1]')
```

```
p1 =
```

$$\begin{pmatrix} 0 \\ 0 \\ l_1 \end{pmatrix}$$

```
p2=str2sym('[l2*cos(q1)*cos(q2); l2*sin(q1)*cos(q2);l2*sin(q2)+l1]')
```

```
p2 =
```

$$\begin{pmatrix} l_2 \cos(q_1) \cos(q_2) \\ l_2 \cos(q_2) \sin(q_1) \\ l_1 + l_2 \sin(q_2) \end{pmatrix}$$

```
p3=str2sym('[l3*cos(q2+q3)*cos(q1)+l2*cos(q1)*cos(q2); l3*cos(q2+q3)*sin(q1)+l2*sin(q1)*cos(q2
```

```
p3 =
```

$$\begin{pmatrix} l_3 \cos(q_2 + q_3) \cos(q_1) + l_2 \cos(q_1) \cos(q_2) \\ l_3 \cos(q_2 + q_3) \sin(q_1) + l_2 \cos(q_2) \sin(q_1) \\ l_1 + l_3 \sin(q_2 + q_3) + l_2 \sin(q_2) \end{pmatrix}$$

```
lc1=38.29 ;
lc2=24.45 ;
lc3=37.9 ;
```

```
l1 = 106;
l2 = 98.7;
l3 = 140.25;
w12=[1 0 0; 0 0 0; 0 0 0];%square of angular velocity of link1
w22=[sin(q1)^2 -sin(q1)*cos(q1) 0; %square of angular velocity of link2
    -sin(q1)*cos(q1) cos(q1)^2 0;
    0 0 0];
m1=258.22;
I1=[290212.21 0 0;
    0 275331.77 0;
    0 0 509323.35];
m2=57.56;
I2=[7409.27 0 0;
    0 52876.31 0;
   0 0 50680.51];
m3=47.17;
I3=[3801.21 0 0;
    0 87085.96 0 ;
    0 0 86685.11];
Jv1=str2sym('[ -lc1*cos(q1), 0, 0; -lc1*sin(q1), 0, 0;           0, 0, 0]')
```

Jv1 =

$$\begin{pmatrix} -\mathrm{lc}_1\cos(q_1) & 0 & 0 \\ -\mathrm{lc}_1\sin(q_1) & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

```
Jv2=str2sym('[                -cos(q1)*(l1 + lc2*sin(q2)),                          -lc2*cos(q
Jv3=str2sym('[-cos(q1)*(l1 + lc3*sin(q2 + q3) + l2*sin(q2)), -cos(q1)*(lc3*sin(q2 + q3) + l2*s
D=m1*Jv1'*Jv1+m2*Jv2'*Jv2+m3*Jv3'*Jv3+I1*w12+(I1+I2)*w22;

d=[(simplify(D(1,1))) (simplify(D(1,2))) (simplify(D(1,3))); (simplify(D(2,1))) (simplify(D(2,
q=str2sym('[q1 q2 q3]')
```

q = $\begin{pmatrix} q_1 & q_2 & q_3 \end{pmatrix}$

```
c=str2sym('[0 0 0;0 0 0;0 0 0]');
    for j=1:3
        for k=1:3
            for i=1:3
            c(k,j)=c(k,j)+(diff(d(k,j),q(i))+diff(d(k,i),q(j))+diff(d(i,j),q(k)))/2;
        end
        end
    end
gr=9810;
g=str2sym('[0; m2*lc2*gr*cos(q2)+m3*gr*l2*cos(q2);m3*g*lc3*cos(q3)]')
```

g =

$$\begin{pmatrix} 0 \\ \mathrm{gr}\, l_2\, m_3 \cos(q_2) + \mathrm{gr}\, \mathrm{lc}_2\, m_2 \cos(q_2) \\ g\, \mathrm{lc}_3\, m_3 \cos(q_3) \end{pmatrix}$$

```
for i=1:3
    for j=1:3
        D(i,j)
    end
end
```

```
ans =
```

$$\frac{5113098092748473 \sin(q_1)^2}{17179869184} + \frac{12911\, \mathrm{lc}_1{}^2 \cos(q_1)^2}{50} + \frac{1439 \cos(q_1)^2\, \sigma_4}{25} + \frac{12911\, \mathrm{lc}_1{}^2 \sin(q_1)^2}{50} + \frac{1439 \sin(q_1)^2\, \sigma_4}{25} + (\mathrm{lc}_2 \cos$$

where

$$\sigma_1 = \mathrm{lc}_3 \cos(q_2 + q_3) \sin(q_1) + l_2 \cos(q_2) \sin(q_1)$$

$$\sigma_2 = \mathrm{lc}_3 \cos(q_2 + q_3) \cos(q_1) + l_2 \cos(q_1) \cos(q_2)$$

$$\sigma_3 = (l_1 + \mathrm{lc}_3 \sin(q_2 + q_3) + l_2 \sin(q_2))^2$$

$$\sigma_4 = (l_1 + \mathrm{lc}_2 \sin(q_2))^2$$

```
ans =
```

$$(\mathrm{lc}_2 \cos(q_2) \cos(q_1)^2 + \mathrm{lc}_2 \cos(q_2) \sin(q_1)^2) \left(\frac{1439\, \mathrm{lc}_2 \cos(q_2) \cos(q_1)^2}{25} + \frac{1439\, \mathrm{lc}_2 \cos(q_2) \sin(q_1)^2}{25} \right) - \frac{5113098092748}{17179}$$

where

$$\sigma_1 = \mathrm{lc}_3 \cos(q_2 + q_3) \sin(q_1) + l_2 \cos(q_2) \sin(q_1)$$

$$\sigma_2 = \mathrm{lc}_3 \cos(q_2 + q_3) \cos(q_1) + l_2 \cos(q_1) \cos(q_2)$$

$$\sigma_3 = l_1 + \mathrm{lc}_2 \sin(q_2)$$

$$\sigma_4 = l_1 + \sigma_6 + l_2 \sin(q_2)$$

$$\sigma_5 = \sigma_6 + l_2 \sin(q_2)$$

$$\sigma_6 = \mathrm{lc}_3 \sin(q_2 + q_3)$$

```
ans =
```

$$\left(\frac{4717\cos(q_1)\ \left(\mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)+l_2\cos(q_1)\cos(q_2)\right)}{100}+\frac{4717\sin(q_1)\ \left(\mathrm{lc}_3\cos(q_2+q_3)\sin(q_1)+l_2\cos(q_2)\sin(q_1\right.}{100}\right.$$

where

$$\sigma_1 = l_1+\mathrm{lc}_3\sin(q_2+q_3)+l_2\sin(q_2)$$

ans =

$$\left(\mathrm{lc}_2\cos(q_2)\cos(q_1)^2+\mathrm{lc}_2\cos(q_2)\sin(q_1)^2\right)\ \left(\frac{1439\,\mathrm{lc}_2\cos(q_2)\cos(q_1)^2}{25}+\frac{1439\,\mathrm{lc}_2\cos(q_2)\sin(q_1)^2}{25}\right)-\frac{5638571879531\text{8}}{17179}$$

where

$$\sigma_1 = \mathrm{lc}_3\cos(q_2+q_3)\sin(q_1)+l_2\cos(q_2)\sin(q_1)$$

$$\sigma_2 = \mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)+l_2\cos(q_1)\cos(q_2)$$

$$\sigma_3 = l_1+\mathrm{lc}_2\sin(q_2)$$

$$\sigma_4 = l_1+\sigma_6+l_2\sin(q_2)$$

$$\sigma_5 = \sigma_6+l_2\sin(q_2)$$

$$\sigma_6 = \mathrm{lc}_3\sin(q_2+q_3)$$

ans =

$$\frac{141009278180786183\cos(q_1)^2}{429496729600}+\frac{10473\sin(q_1)^2}{100}+\frac{4717\cos(q_1)^2\,\sigma_3}{100}+\left(\mathrm{lc}_2\cos(q_2)\cos(q_1)^2+\mathrm{lc}_2\cos(q_2)\sin(q_1)^2\right)\ \left(\frac{143}{}\right.$$

where

$$\sigma_1 = \mathrm{lc}_3\cos(q_2+q_3)\sin(q_1)+l_2\cos(q_2)\sin(q_1)$$

$$\sigma_2 = \mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)+l_2\cos(q_1)\cos(q_2)$$

$$\sigma_3 = (\mathrm{lc}_3\sin(q_2+q_3)+l_2\sin(q_2))^2$$

ans =

$$\frac{4717\cos(q_1)^2}{100}+\left(\frac{4717\cos(q_1)\ \left(\mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)+l_2\cos(q_1)\cos(q_2)\right)}{100}+\frac{4717\sin(q_1)\ \left(\mathrm{lc}_3\cos(q_2+q_3)\sin(q_1)+\right.}{100}\right.$$

where

$$\sigma_1 = \mathrm{lc}_3\sin(q_2+q_3)+l_2\sin(q_2)$$

ans =

$$(\cos(q_1)\ (\mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)+l_2\cos(q_1)\cos(q_2))+\sin(q_1)\ (\mathrm{lc}_3\cos(q_2+q_3)\sin(q_1)+l_2\cos(q_2)\sin(q_1)))\ \left(\frac{4717\ }{}\right.$$

where

$$\sigma_1 = l_1+\mathrm{lc}_3\sin(q_2+q_3)+l_2\sin(q_2)$$

ans =

$$\frac{4717\cos(q_1)^2}{100}+(\cos(q_1)\ (\mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)+l_2\cos(q_1)\cos(q_2))+\sin(q_1)\ (\mathrm{lc}_3\cos(q_2+q_3)\sin(q_1)+l_2\cos(q_2)\ s$$

where

$$\sigma_1 = \mathrm{lc}_3\sin(q_2+q_3)+l_2\sin(q_2)$$

ans =

$$\frac{4717\cos(q_1)^2}{100}+\frac{4717\sin(q_1)^2}{100}+\left(\mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)^2+\mathrm{lc}_3\cos(q_2+q_3)\sin(q_1)^2\right)\ \left(\frac{4717\,\mathrm{lc}_3\cos(q_2+q_3)\cos(q_1)^2}{100}\right.$$

where

$$\sigma_1 = \sin(q_2+q_3)^2$$

```
for i=1:3
    for j=1:3
        c(i,j)
    end
end
```

ans =

$$\frac{15339294278245419\sin(2\,q_1)}{34359738368}-\frac{1343958746535035\cos(2\,q_1)}{4294967296}+\frac{4717\,l_1\,l_2\cos(q_2)}{100}+\frac{1439\,l_1\,\mathrm{lc}_2\cos(q_2)}{25}-\frac{4717\,l_2\,\mathrm{lc}_3\sin(q_3}{100}$$

ans =

$$\frac{4717\,l_1\,l_2\cos(q_2)}{50}-\frac{5638571879531807\cos(q_1)\sin(q_1)}{17179869184}-\frac{5113098092748473\cos(2\,q_1)}{17179869184}+\frac{2878\,l_1\,\mathrm{lc}_2\cos(q_2)}{25}-\frac{4717\,l_2\,\mathrm{lc}_3\ s}{100}$$

ans =

$$\frac{4717\,\mathrm{lc}_3\ (l_1\cos(q_2+q_3)-l_2\sin(q_3))}{100}-\frac{4717\,l_2\,\mathrm{lc}_3\sin(q_3)}{50}+\frac{4717\,l_1\,\mathrm{lc}_3\cos(q_2+q_3)}{50}$$

ans =

$$\frac{4717\,l_1\,l_2\cos(q_2)}{50}-\frac{5638571879531807\cos(q_1)\sin(q_1)}{17179869184}-\frac{5638571879531807\cos(2\,q_1)}{17179869184}+\frac{2878\,l_1\,\mathrm{lc}_2\cos(q_2)}{25}-\frac{4717\,l_2\,\mathrm{lc}_3\ s}{100}$$

ans =

$$\frac{4717\,l_1\,l_2\cos(q_2)}{100}-\frac{5638571879531807\cos(q_1)\sin(q_1)}{17179869184}+\frac{1439\,l_1\,\mathrm{lc}_2\cos(q_2)}{25}-\frac{4717\,l_2\,\mathrm{lc}_3\sin(q_3)}{100}+\frac{4717\,l_1\,\mathrm{lc}_3\cos(q_2+q_3)}{100}$$

ans =

$$\frac{4717\,l_1\,\mathrm{lc}_3\cos(q_2+q_3)}{100}-\frac{14151\,l_2\,\mathrm{lc}_3\sin(q_3)}{100}$$

ans =

$$\frac{4717\,\mathrm{lc}_3\,\left(l_1\cos(q_2+q_3)-l_2\sin(q_3)\right)}{100}-\frac{4717\,l_2\,\mathrm{lc}_3\sin(q_3)}{50}+\frac{4717\,l_1\,\mathrm{lc}_3\cos(q_2+q_3)}{50}$$

ans =

$$\frac{4717\,l_1\,\mathrm{lc}_3\cos(q_2+q_3)}{100}-\frac{14151\,l_2\,\mathrm{lc}_3\sin(q_3)}{100}$$

ans =

$$\frac{4717\,\mathrm{lc}_3\,\left(l_1\cos(q_2+q_3)-l_2\sin(q_3)\right)}{100}-\frac{4717\,l_2\,\mathrm{lc}_3\sin(q_3)}{100}$$

```
% ddot=str2sym('[0 0 0;0 0 0;0 0 0]');
%     for j=1:3
%         for k=1:3
%             for i=1:3
%             ddot(k,j)=ddot(k,j)+(diff(d(k,j),q(i)));
%         end
%     end
%     end
% N=simplify(ddot)-2*simplify(c)
%
% tf = issymmetric(N,'skew')
```