```
(*********************************)
(*Dynamics of A Planar Mechanism*)
(*********************************)
SetOptions[EvaluationNotebook[], CellContext → Notebook]

(*Defining Absolute Coordinates*)
Do[(r_j = {x_j[t], y_j[t]}), {j, 4}]
q = Join[r_1, {θ_1[t]}, r_2, {θ_2[t]}, r_3, {θ_3[t]}, r_4, {θ_4[t]}]
```

$$\{x_1[t], y_1[t], \theta_1[t], x_2[t], y_2[t], \theta_2[t], x_3[t], y_3[t], \theta_3[t], x_4[t], y_4[t], \theta_4[t]\}$$

```
(*Defining Constraints*)
Φ = {y_1[t], θ_1[t], x_2[t], θ_2[t], x_2[t] - x_1[t] + y_2[t] - y_1[t],
  θ_2[t] - θ_1[t], x_1[t] - x_3[t], y_1[t] - y_3[t], x_2[t] - x_4[t], y_2[t] - y_4[t],
  x_3[t] - Sin[θ_3[t]] - x_4[t] - Cos[θ_4[t]], y_3[t] + Cos[θ_3[t]] - y_4[t] - Sin[θ_4[t]]}
```

$$\{y_1[t], \theta_1[t], x_2[t], \theta_2[t], -x_1[t] + x_2[t] - y_1[t] + y_2[t], -\theta_1[t] + \theta_2[t], x_1[t] - x_3[t], y_1[t] - y_3[t], x_2[t] - x_4[t], y_2[t] - y_4[t], -\cos[\theta_4[t]] - \sin[\theta_3[t]] + x_3[t] - x_4[t], \cos[\theta_3[t]] - \sin[\theta_4[t]] + y_3[t] - y_4[t]\}$$

```
MatrixForm[%]
```

$$\begin{pmatrix} y_1[t] \\ \theta_1[t] \\ x_2[t] \\ \theta_2[t] \\ -x_1[t] + x_2[t] - y_1[t] + y_2[t] \\ -\theta_1[t] + \theta_2[t] \\ x_1[t] - x_3[t] \\ y_1[t] - y_3[t] \\ x_2[t] - x_4[t] \\ y_2[t] - y_4[t] \\ -\cos[\theta_4[t]] - \sin[\theta_3[t]] + x_3[t] - x_4[t] \\ \cos[\theta_3[t]] - \sin[\theta_4[t]] + y_3[t] - y_4[t] \end{pmatrix}$$

```
J = D[Φ, {q}] (* Jacobian Matrix *)
```

$$\{\{0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0\}, \{0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0\}, \{0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0\}, \{0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0\}, \{-1, -1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0\}, \{0, 0, -1, 0, 0, 1, 0, 0, 0, 0, 0, 0\}, \{1, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\}, \{0, 1, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0\}, \{0, 0, 0, 1, 0, 0, 0, 0, 0, -1, 0, 0\}, \{0, 0, 0, 0, 1, 0, 0, 0, 0, 0, -1, 0\}, \{0, 0, 0, 0, 0, 0, 1, 0, -\cos[\theta_3[t]], -1, 0, \sin[\theta_4[t]]\}, \{0, 0, 0, 0, 0, 0, 0, 1, -\sin[\theta_3[t]], 0, -1, -\cos[\theta_4[t]]\}\}$$

```
q' = D[q, t]
```

$$\{x_1'[t], y_1'[t], \theta_1'[t], x_2'[t], y_2'[t], \theta_2'[t], x_3'[t], y_3'[t], \theta_3'[t], x_4'[t], y_4'[t], \theta_4'[t]\}$$

```
l1 = l2 = 1 / 2;
l3 = l4 = 1;
m = 1;
(*θ3=θ4=0;*)
```

$$M_1 = \left\{\{m, 0, 0\}, \{0, m, 0\}, \left\{0, 0, \frac{m\, l_1^2}{12}\right\}\right\}$$

$$M_2 = \left\{\{m, 0, 0\}, \{0, m, 0\}, \left\{0, 0, \frac{m\, l_2^2}{12}\right\}\right\}$$

$$M_3 = \left\{\left\{m, 0, \frac{1}{2}(-m)\, l_3 \text{Sin}[\theta_3[t]]\right\}, \left\{0, m, \frac{1}{2} m\, l_3 \text{Cos}[\theta_3[t]]\right\}, \left\{\frac{1}{2}(-m)\, l_3 \text{Sin}[\theta_3[t]], \frac{1}{2} m\, l_3 \text{Cos}[\theta_3[t]], \frac{m\, l_3^2}{3}\right\}\right\}$$

$$M_4 = \left\{\left\{m, 0, \frac{1}{2}(-m)\, l_4 \text{Sin}[\theta_4[t]]\right\}, \left\{0, m, \frac{1}{2} m\, l_4 \text{Cos}[\theta_4[t]]\right\}, \left\{\frac{1}{2}(-m)\, l_4 \text{Sin}[\theta_4[t]], \frac{1}{2} m\, l_4 \text{Cos}[\theta_4[t]], \frac{m\, l_4^2}{3}\right\}\right\}$$

$$\left\{\{1, 0, 0\}, \{0, 1, 0\}, \left\{0, 0, \frac{1}{48}\right\}\right\}$$

$$\left\{\{1, 0, 0\}, \{0, 1, 0\}, \left\{0, 0, \frac{1}{48}\right\}\right\}$$

$$\left\{\left\{1, 0, -\frac{1}{2}\text{Sin}[\theta_3[t]]\right\}, \left\{0, 1, \frac{1}{2}\text{Cos}[\theta_3[t]]\right\}, \left\{-\frac{1}{2}\text{Sin}[\theta_3[t]], \frac{1}{2}\text{Cos}[\theta_3[t]], \frac{1}{3}\right\}\right\}$$

$$\left\{\left\{1, 0, -\frac{1}{2}\text{Sin}[\theta_4[t]]\right\}, \left\{0, 1, \frac{1}{2}\text{Cos}[\theta_4[t]]\right\}, \left\{-\frac{1}{2}\text{Sin}[\theta_4[t]], \frac{1}{2}\text{Cos}[\theta_4[t]], \frac{1}{3}\right\}\right\}$$

```
M = ArrayFlatten[{{M1, 0, 0, 0}, {0, M2, 0, 0}, {0, 0, M3, 0}, {0, 0, 0, M4}}]
```

$$\left\{\{1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0\}, \{0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0\}, \left\{0, 0, \frac{1}{48}, 0, 0, 0, 0, 0, 0, 0, 0, 0\right\}, \{0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0\}, \{0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0\}, \left\{0, 0, 0, 0, 0, \frac{1}{48}, 0, 0, 0, 0, 0, 0\right\}, \left\{0, 0, 0, 0, 0, 0, 1, 0, -\frac{1}{2}\text{Sin}[\theta_3[t]], 0, 0, 0\right\}, \left\{0, 0, 0, 0, 0, 0, 0, 1, \frac{1}{2}\text{Cos}[\theta_3[t]], 0, 0, 0\right\}, \left\{0, 0, 0, 0, 0, 0, 0, 0, -\frac{1}{2}\text{Sin}[\theta_3[t]], \frac{1}{2}\text{Cos}[\theta_3[t]], \frac{1}{3}, 0, 0, 0\right\}, \left\{0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, -\frac{1}{2}\text{Sin}[\theta_4[t]]\right\}, \left\{0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, \frac{1}{2}\text{Cos}[\theta_4[t]]\right\}, \left\{0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -\frac{1}{2}\text{Sin}[\theta_4[t]], \frac{1}{2}\text{Cos}[\theta_4[t]], \frac{1}{3}\right\}\right\}$$

```
MatrixRank[J]
```

```
11
```

```
(*RowReduce[J] //MatrixForm*)
```

```
J = Drop[J, {2}, 0] (*Eliminating a dependent constraint, arbitrarily*)
```

```
{{0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},
 {0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0}, {0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0},
 {-1, -1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0}, {0, 0, -1, 0, 0, 1, 0, 0, 0, 0, 0, 0},
 {1, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0}, {0, 1, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0},
 {0, 0, 0, 1, 0, 0, 0, 0, 0, -1, 0, 0}, {0, 0, 0, 0, 1, 0, 0, 0, 0, 0, -1, 0},
 {0, 0, 0, 0, 0, 0, 1, 0, -Cos[θ3[t]], -1, 0, Sin[θ4[t]]},
 {0, 0, 0, 0, 0, 0, 0, 1, -Sin[θ3[t]], 0, -1, -Cos[θ4[t]]}}
```

```
JIn = PseudoInverse[J]
```

A very large output was generated. Here is a sample of it:

{ <<1>> }

Show Less | Show More | Show Full Output | Set Size Limit...

```
Qe = {1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0}
```

```
{1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0}
```

```
q′ = D[q, t]
```

```
{x1′[t], y1′[t], θ1′[t], x2′[t], y2′[t], θ2′[t], x3′[t], y3′[t], θ3′[t], x4′[t], y4′[t], θ4′[t]}
```

```
Qd = -(∂{q} (J.q′)).q′
```

```
{0, 0, 0, 0, 0, 0, 0, 0, -Sin[θ3[t]] θ3′[t]^2 - Cos[θ4[t]] θ4′[t]^2,
 Cos[θ3[t]] θ3′[t]^2 - Sin[θ4[t]] θ4′[t]^2}
```

MIn = Inverse[M]

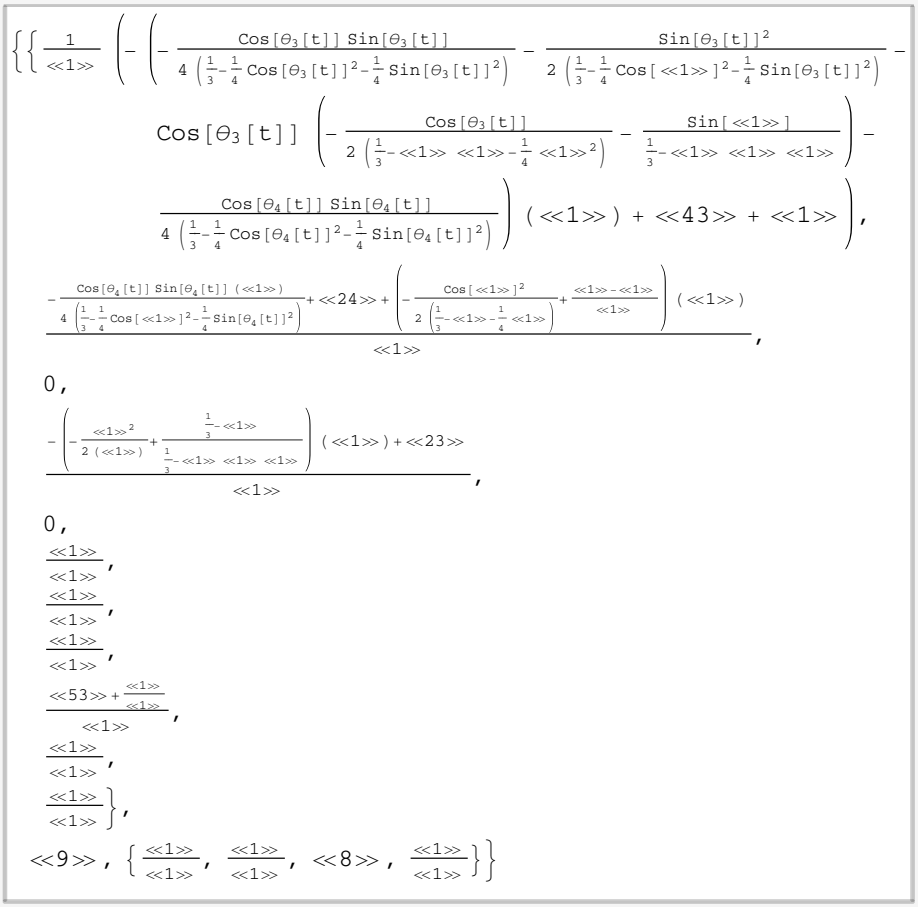
$$\left\{\{1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0\}, \{0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0\},\right.$$
$$\{0, 0, 48, 0, 0, 0, 0, 0, 0, 0, 0, 0\}, \{0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0\},$$
$$\{0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0\}, \{0, 0, 0, 0, 0, 48, 0, 0, 0, 0, 0, 0\},$$
$$\left\{0, 0, 0, 0, 0, 0, \frac{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2}{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2},\right.$$
$$\left. -\frac{\text{Cos}[\theta_3[t]]\,\text{Sin}[\theta_3[t]]}{4\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2\right)}, \frac{\text{Sin}[\theta_3[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2\right)}, 0, 0, 0\right\},$$
$$\left\{0, 0, 0, 0, 0, 0, -\frac{\text{Cos}[\theta_3[t]]\,\text{Sin}[\theta_3[t]]}{4\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2\right)},\right.$$
$$\left.\frac{\frac{1}{3} - \frac{1}{4}\text{Sin}[\theta_3[t]]^2}{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2}, -\frac{\text{Cos}[\theta_3[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2\right)}, 0, 0, 0\right\},$$
$$\left\{0, 0, 0, 0, 0, 0, \frac{\text{Sin}[\theta_3[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2\right)},\right.$$
$$\left. -\frac{\text{Cos}[\theta_3[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2\right)}, \frac{1}{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_3[t]]^2 - \frac{1}{4}\text{Sin}[\theta_3[t]]^2}, 0, 0, 0\right\},$$
$$\left\{0, 0, 0, 0, 0, 0, 0, 0, 0, \frac{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2}{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2},\right.$$
$$\left. -\frac{\text{Cos}[\theta_4[t]]\,\text{Sin}[\theta_4[t]]}{4\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)}, \frac{\text{Sin}[\theta_4[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)}\right\},$$
$$\left\{0, 0, 0, 0, 0, 0, 0, 0, 0, -\frac{\text{Cos}[\theta_4[t]]\,\text{Sin}[\theta_4[t]]}{4\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)},\right.$$
$$\left.\frac{\frac{1}{3} - \frac{1}{4}\text{Sin}[\theta_4[t]]^2}{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2}, -\frac{\text{Cos}[\theta_4[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)}\right\},$$
$$\left\{0, 0, 0, 0, 0, 0, 0, 0, 0, \frac{\text{Sin}[\theta_4[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)},\right.$$
$$\left.\left. -\frac{\text{Cos}[\theta_4[t]]}{2\left(\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)}, \frac{1}{\frac{1}{3} - \frac{1}{4}\text{Cos}[\theta_4[t]]^2 - \frac{1}{4}\text{Sin}[\theta_4[t]]^2}\right\}\right\}$$

Jt = Transpose[J]

$$\{\{0, 0, 0, -1, 0, 1, 0, 0, 0, 0, 0\}, \{1, 0, 0, -1, 0, 0, 1, 0, 0, 0, 0\},$$
$$\{0, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0\}, \{0, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0\},$$
$$\{0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0\}, \{0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0\},$$
$$\{0, 0, 0, 0, 0, -1, 0, 0, 0, 1, 0\}, \{0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 1\},$$
$$\{0, 0, 0, 0, 0, 0, 0, 0, 0, -\text{Cos}[\theta_3[t]], -\text{Sin}[\theta_3[t]]\},$$
$$\{0, 0, 0, 0, 0, 0, 0, -1, 0, -1, 0\}, \{0, 0, 0, 0, 0, 0, 0, 0, -1, 0, -1\},$$
$$\{0, 0, 0, 0, 0, 0, 0, 0, 0, \text{Sin}[\theta_4[t]], -\text{Cos}[\theta_4[t]]\}\}$$

```
JMinJt = Inverse[J.MIn.Jt]
```

A very large output was generated. Here is a sample of it:



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```
(*q''=MIn.Qe+MIn.Jt.(JMinJt.(Qd-J.MIn.Qe))*)
```

```
eqs =
 ∂t∂tq - (MIn.Qe + MIn.Jt.(JMinJt.(Qd - J.MIn.Qe))) == {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0}
(*eqns1 = ∂t∂tq - (MIn.Qe+MIn.Jt.(JMinJt.(Qd-J.MIn.Qe)))*)
```

A very large output was generated. Here is a sample of it:

$$\left\{-1+\frac{\text{<<1>>}}{\text{<<1>>}}-\frac{\frac{\text{Cos}[\theta_4[t]]\,\text{Sin}[\theta_4[t]]\left(-\frac{\text{<<1>>}}{24\,(\text{<<1>>})\,\text{<<1>>}^2}+\frac{\text{<<1>>}}{\text{<<1>>}}+\text{<<6>>}\right)}{4\left(\frac{1}{3}-\frac{1}{4}\text{Cos}[\text{<<1>>}]^2-\frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)}+\text{<<43>>}}{\text{<<1>>}}-\frac{\left(-\frac{\text{<<1>>}^2}{6\,\text{<<1>>}^2}+\text{<<17>>}\right)\left(-\frac{\text{<<1>>}^2}{2\,\text{<<1>>}}+\frac{\text{<<1>>}}{\text{<<1>>}}\right)+\text{<<40>>}}{\text{<<1>>}}+\right.$$

$$\frac{\text{<<1>>}}{\text{<<1>>}}+\frac{(\text{<<1>>})\,(\text{<<1>>})}{\text{<<1>>}}-\frac{(\text{<<1>>})\,(\text{<<1>>})}{\text{<<1>>}}+\frac{(\text{<<1>>})\left(\text{Cos}[\theta_3[t]]\,\theta_3'[t]^2-\text{Sin}[\theta_4[t]]\,\text{<<1>>}'[t]^2\right)}{\text{<<1>>}}-$$

$$\frac{\left(\frac{\text{Cos}[\theta_3[t]]\,\text{Cos}[\theta_4[t]]^2\,\text{Sin}[\theta_3[t]]\,\text{Sin}[\theta_4[t]]^2}{64\left(\frac{1}{3}-\frac{1}{4}\text{Cos}[\theta_3[t]]^2-\frac{1}{4}\text{Sin}[\theta_3[t]]^2\right)\left(\frac{1}{3}-\frac{1}{4}\text{Cos}[\text{<<1>>}]^2-\frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)^2}-\frac{\text{Cos}[\theta_4[t]]\,\text{<<1>>}\,(\text{<<1>>})}{4\left(\frac{1}{3}-\text{<<1>>}-\frac{1}{4}\,\text{<<1>>}^2\right)}+\text{<<67>>}+\frac{\text{Cos}[\theta_4[t]]\,\text{Sin}[\theta_4[t]]\,(\text{<<1>>})}{4\left(\frac{1}{3}-\frac{1}{4}\text{Cos}[\text{<<1>>}]^2-\frac{1}{4}\text{Sin}[\theta_4[t]]^2\right)}\right)(\text{<<1>>})}{\text{<<1>>}}$$

$$\left.+x_1''[t],\ \text{<<19>>}+\text{<<1>>},\ \text{<<8>>},\ \text{<<1>>},\ \text{<<1>>}\right\}==\{\text{<<1>>}\}$$

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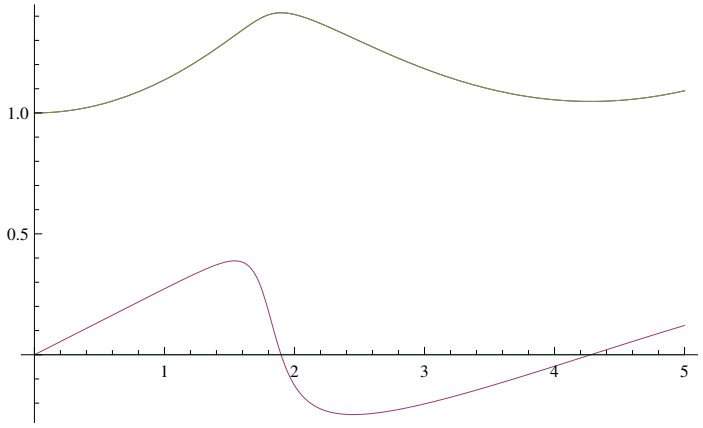
```
(*λ = JMinJt.(Qd-J.MIn.Qe)*)
(*Qc = {Q1[t],Q2[t],Q3[t],Q4[t],Q5[t],Q6[t],Q7[t],Q8[t],Q9[t],Q10[t],Q11[t],Q12[t]}
   eqns2 = Qc -Jt.JMInJt.(Qd-J.MIn.Qe)*)
(*eqns2 = Qc- (Qe- M.Inverse[J].Qd)*)

(*eqns=Join[eqns1,eqns2]=={0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0}*)
```

```
s = NDSolve[{eqs, x1[0] == 1, y1[0] == 0, θ1[0] == 0, x1'[0] == 0, y1'[0] == 0,
    θ1'[0] == 0, x2[0] == 0, y2[0] == 1, θ2[0] == 0, x2'[0] == 0, y2'[0] == 0, θ2'[0] == 0,
    x3[0] == 1, y3[0] == 0, θ3[0] == 0, x3'[0] == 0, y3'[0] == 0, θ3'[0] == 0,
    x4[0] == 0, y4[0] == 1, θ4[0] == 0, x4'[0] == 0, y4'[0] == 0, θ4'[0] == 0},
   {x1, y1, θ1, x2, y2, θ2, x3, y3, θ3, x4, y4, θ4, x1', y1', θ1', x2', y2', θ2', x3', y3',
    θ3', x4', y4', θ4'}, {t, 0, 5}, Method -> {"EquationSimplification" -> "Solve"}]
```

```
{{x1 → InterpolatingFunction[{{0., 5.}}, <>],
  y1 → InterpolatingFunction[{{0., 5.}}, <>],
  θ1 → InterpolatingFunction[{{0., 5.}}, <>],
  x2 → InterpolatingFunction[{{0., 5.}}, <>],
  y2 → InterpolatingFunction[{{0., 5.}}, <>],
  θ2 → InterpolatingFunction[{{0., 5.}}, <>],
  x3 → InterpolatingFunction[{{0., 5.}}, <>],
  y3 → InterpolatingFunction[{{0., 5.}}, <>],
  θ3 → InterpolatingFunction[{{0., 5.}}, <>],
  x4 → InterpolatingFunction[{{0., 5.}}, <>],
  y4 → InterpolatingFunction[{{0., 5.}}, <>],
  θ4 → InterpolatingFunction[{{0., 5.}}, <>],
  x1' → InterpolatingFunction[{{0., 5.}}, <>],
  y1' → InterpolatingFunction[{{0., 5.}}, <>],
  θ1' → InterpolatingFunction[{{0., 5.}}, <>],
  x2' → InterpolatingFunction[{{0., 5.}}, <>],
  y2' → InterpolatingFunction[{{0., 5.}}, <>],
  θ2' → InterpolatingFunction[{{0., 5.}}, <>],
  x3' → InterpolatingFunction[{{0., 5.}}, <>],
  y3' → InterpolatingFunction[{{0., 5.}}, <>],
  θ3' → InterpolatingFunction[{{0., 5.}}, <>],
  x4' → InterpolatingFunction[{{0., 5.}}, <>],
  y4' → InterpolatingFunction[{{0., 5.}}, <>],
  θ4' → InterpolatingFunction[{{0., 5.}}, <>]}}
```

```
Plot[Evaluate[{x3[t], x3'[t] , y2[t], θ1[t]} /. s], {t, 0, 5}, PlotStyle → Automatic]
```



```
θ3[2] /. s
J /. t → 2 /. s
λ = JMinJt.(Qd - J.MIn.Qe)
```

```
{0.886271}
```

```
{{{0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0},
  {0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0}, {0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0},
  {-1, -1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0}, {0, 0, -1, 0, 0, 1, 0, 0, 0, 0, 0, 0},
  {1, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0}, {0, 1, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0},
  {0, 0, 0, 1, 0, 0, 0, 0, 0, -1, 0, 0}, {0, 0, 0, 0, 1, 0, 0, 0, 0, 0, -1, 0},
  {0, 0, 0, 0, 0, 0, 1, 0, -0.632306, -1, 0, -0.774719},
  {0, 0, 0, 0, 0, 0, 0, 1, -0.774719, 0, -1, -0.632306}}}
```

A very large output was generated. Here is a sample of it:

$$\left\{\frac{1}{\ll 1\gg}\left(-\left(-\frac{\cos[\theta_4[t]]^2}{2\left(\frac{1}{3}-\frac{1}{4}\cos[\theta_4[t]]^2-\frac{1}{4}\sin[\theta_4[t]]^2\right)}+\frac{\frac{1}{3}-\frac{1}{4}\sin[\theta_4[t]]^2}{\frac{1}{3}-\frac{1}{4}\cos[\theta_4[t]]^2-\frac{1}{4}\sin[\theta_4[t]]^2}\right)\right.\right.$$
$$\left(\frac{\cos[\theta_4[t]]\sin[\theta_4[t]]\left(\ll 32\gg+\frac{\ll 1\gg}{\ll 1\gg}\right)}{4\left(\frac{1}{3}-\frac{1}{4}\cos[\theta_4[t]]^2-\frac{1}{4}\sin[\theta_4[t]]^2\right)}-\right.$$
$$\left.\left.\left(\frac{\cos[\ll 1\gg]^2}{9\,(\ll 1\gg)^3}-\frac{\ll 1\gg}{6\ll 1\gg}+\ll 41\gg+\frac{\ll 1\gg^2\ll 1\gg^2}{16\,(\ll 1\gg)\,(\ll 1\gg)}\right)\,(\ll 1\gg)\right)+\ll 23\gg\right)-$$
$$\frac{-(\ll 1\gg)\left(-\frac{1}{9\,(\ll 1\gg)^2}+\frac{\ll 1\gg}{\ll 1\gg}+\frac{\ll 1\gg}{\ll 1\gg}+\frac{\cos[\theta_3[t]]\ll 2\gg\sin[\theta_4[t]]}{16\,(\ll 1\gg)\left(\frac{1}{3}-\frac{1}{4}\ll 1\gg^2-\frac{1}{4}\ll 1\gg^2\right)}\right)+\ll 60\gg}{\ll 1\gg}+$$
$$\frac{(\ll 1\gg)\left(-\sin[\theta_3[t]]\ll 1\gg'[t]^2-\cos[\ll 1\gg[t]]\ll 1\gg\right)}{\ll 1\gg}+$$
$$\frac{\left(\ll 43\gg+\frac{\ll 1\gg}{\ll 1\gg}\right)\left(\cos[\theta_3[t]]\theta_3'[t]^2-\sin[\theta_4[t]]\theta_4'[t]^2\right)}{\ll 1\gg},$$
$$\ll 1\gg,\ 0,\ \ll 6\gg,\ \ll 1\gg,$$
$$\frac{\ll 1\gg}{\ll 1\gg}-\frac{\ll 1\gg}{\ll 1\gg}+\frac{\ll 1\gg}{\ll 1\gg}+\frac{(\ll 1\gg)\,(\ll 1\gg\ \ll 1\gg-\ll 1\gg)}{\ll 1\gg}\Bigg\}$$

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```
λ /. t → 1 /. s
```

```
{{0.539284, -0.528874, 0, 0.352806, 0, -0.377552,
  -0.186478, 0.176067, -0.0831644, -0.141989, 0.0421465}}
```

```
Dimensions[λ]
(*This should come out to be 11, and not 12*)
```

```
{11}
```

```
Table[Plot[Evaluate[λ[[j]] /. s], {t, 0, 5}, PlotStyle → Automatic], {j, 1, 11}]
```