In[]:=
```
Clear["`*"]
```

In[]:=
```
r = Sqrt[Lr^2 + Lp^2/4 Sin[α[t]]^2]
```

Out[]=
$$\sqrt{\text{Lr}^2 + \frac{1}{4}\,\text{Lp}^2\,\text{Sin}[\alpha[t]]^2}$$

In[]:=
```
th = θ[t] - ArcTan[Lp Sin[α[t]] / (2 Lr)]
```

Out[]=
$$-\text{ArcTan}\left[\frac{\text{Lp}\,\text{Sin}[\alpha[t]]}{2\,\text{Lr}}\right] + \theta[t]$$

In[]:=
```
z = Lp Cos[α[t]] / 2
```

Out[]=
$$\frac{1}{2}\,\text{Lp}\,\text{Cos}[\alpha[t]]$$

In[]:=
```
vsq = D[r, t]^2 + r^2 D[th, t]^2 + D[z, t]^2
```

Out[]=
$$\frac{1}{4}\,\text{Lp}^2\,\text{Sin}[\alpha[t]]^2\,\alpha'[t]^2 + \frac{\text{Lp}^4\,\text{Cos}[\alpha[t]]^2\,\text{Sin}[\alpha[t]]^2\,\alpha'[t]^2}{16\left(\text{Lr}^2 + \frac{1}{4}\,\text{Lp}^2\,\text{Sin}[\alpha[t]]^2\right)} + \left(\text{Lr}^2 + \frac{1}{4}\,\text{Lp}^2\,\text{Sin}[\alpha[t]]^2\right)\left(-\frac{\text{Lp}\,\text{Cos}[\alpha[t]]\,\alpha'[t]}{2\,\text{Lr}\left(1 + \frac{\text{Lp}^2\,\text{Sin}[\alpha[t]]^2}{4\,\text{Lr}^2}\right)} + \theta'[t]\right)^2$$

In[]:=
```
vsqs = FullSimplify[vsq, Trig → False]
```

Out[]=
$$\frac{1}{4}\left(\text{Lp}^2\,\alpha'[t]^2 - 4\,\text{Lp}\,\text{Lr}\,\text{Cos}[\alpha[t]]\,\alpha'[t]\,\theta'[t] + \left(4\,\text{Lr}^2 + \text{Lp}^2\,\text{Sin}[\alpha[t]]^2\right)\theta'[t]^2\right)$$

In[]:=
```
Collect[vsqs, {θ''[t], θ'[t], α''[t], α'[t], α'[t] × θ'[t]}]
```

Out[]=
$$\frac{1}{4}\,\text{Lp}^2\,\alpha'[t]^2 - \text{Lp}\,\text{Lr}\,\text{Cos}[\alpha[t]]\,\alpha'[t]\,\theta'[t] + \frac{1}{4}\left(4\,\text{Lr}^2 + \text{Lp}^2\,\text{Sin}[\alpha[t]]^2\right)\theta'[t]^2$$

In[]:=
```
T = 1/2 Jr D[θ[t], t]^2 + 1/2 Jp D[α[t], t]^2 + 1/2 mp vsqs
```

Out[]=
$$\frac{1}{2}\,\text{Jp}\,\alpha'[t]^2 + \frac{1}{2}\,\text{Jr}\,\theta'[t]^2 + \frac{1}{8}\,\text{mp}\left(\text{Lp}^2\,\alpha'[t]^2 - 4\,\text{Lp}\,\text{Lr}\,\text{Cos}[\alpha[t]]\,\alpha'[t]\,\theta'[t] + \left(4\,\text{Lr}^2 + \text{Lp}^2\,\text{Sin}[\alpha[t]]^2\right)\theta'[t]^2\right)$$

In[]:=
```
V = mp g Lp / 2 Cos[α[t]]
```

Out[]=
$$\frac{1}{2}\,\text{g}\,\text{Lp}\,\text{mp}\,\text{Cos}[\alpha[t]]$$

In[]:=
```
L = T - V
```

Out[]=
$$-\frac{1}{2}\,\text{g}\,\text{Lp}\,\text{mp}\,\text{Cos}[\alpha[t]] + \frac{1}{2}\,\text{Jp}\,\alpha'[t]^2 + \frac{1}{2}\,\text{Jr}\,\theta'[t]^2 + \frac{1}{8}\,\text{mp}\left(\text{Lp}^2\,\alpha'[t]^2 - 4\,\text{Lp}\,\text{Lr}\,\text{Cos}[\alpha[t]]\,\alpha'[t]\,\theta'[t] + \left(4\,\text{Lr}^2 + \text{Lp}^2\,\text{Sin}[\alpha[t]]^2\right)\theta'[t]^2\right)$$

In[•]:=
```
eq1 = D[D[L, θ'[t]], t] - D[L, θ[t]]
```

Out[•]=
$$\mathrm{Jr}\,\theta''[t] + \frac{1}{16}\,\mathrm{mp}\,\left(8\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{Sin}[\alpha[t]]\,\alpha'[t]^2 + 4\,\mathrm{Lp}^2\,\mathrm{Sin}[2\,\alpha[t]]\,\alpha'[t]\,\theta'[t] - 8\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{Cos}[\alpha[t]]\,\alpha''[t] + 2\,\left(\mathrm{Lp}^2 + 8\,\mathrm{Lr}^2 - \mathrm{Lp}^2\,\mathrm{Cos}[2\,\alpha[t]]\right)\,\theta''[t]\right)$$

In[•]:=
```
Collect[eq1, {θ''[t], θ'[t], α''[t], α'[t], α'[t] × θ'[t]}]
```

Out[•]=
$$\frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Sin}[\alpha[t]]\,\alpha'[t]^2 + \frac{1}{4}\,\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[2\,\alpha[t]]\,\alpha'[t]\,\theta'[t] - \frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Cos}[\alpha[t]]\,\alpha''[t] + \left(\mathrm{Jr} + \frac{1}{8}\,\mathrm{mp}\,\left(\mathrm{Lp}^2 + 8\,\mathrm{Lr}^2 - \mathrm{Lp}^2\,\mathrm{Cos}[2\,\alpha[t]]\right)\right)\,\theta''[t]$$

In[•]:=
```
Coefficient[eq1, α'[t]^2]
```

Out[•]=
$$\frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Sin}[\alpha[t]]$$

In[•]:=
```
eq2 = D[D[L, α'[t]], t] - D[L, α[t]] // Expand
```

Out[•]=
$$-\frac{1}{2}\,\mathrm{g}\,\mathrm{Lp}\,\mathrm{mp}\,\mathrm{Sin}[\alpha[t]] - \frac{1}{8}\,\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[2\,\alpha[t]]\,\theta'[t]^2 + \mathrm{Jp}\,\alpha''[t] + \frac{1}{4}\,\mathrm{Lp}^2\,\mathrm{mp}\,\alpha''[t] - \frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Cos}[\alpha[t]]\,\theta''[t]$$

In[•]:=
```
Collect[eq2, {θ''[t], θ'[t], α''[t], α'[t], α'[t] × θ'[t]}]
```

Out[•]=
$$-\frac{1}{2}\,\mathrm{g}\,\mathrm{Lp}\,\mathrm{mp}\,\mathrm{Sin}[\alpha[t]] - \frac{1}{8}\,\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[2\,\alpha[t]]\,\theta'[t]^2 + \left(\mathrm{Jp} + \frac{\mathrm{Lp}^2\,\mathrm{mp}}{4}\right)\,\alpha''[t] - \frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Cos}[\alpha[t]]\,\theta''[t]$$

In[•]:=
```
H = {{(Jr + 1/4 mp Lp^2 Sin[α[t]]^2 + mp Lr^2), -1/2 Lp Lr mp Cos[α[t]]},
  {-1/2 Lp Lr mp Cos[α[t]], (Jp + Lp^2 mp/4)}}
```

Out[•]=
$$\left\{\left\{\mathrm{Jr} + \mathrm{Lr}^2\,\mathrm{mp} + \frac{1}{4}\,\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[\alpha[t]]^2,\ -\frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Cos}[\alpha[t]]\right\},\ \left\{-\frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Cos}[\alpha[t]],\ \mathrm{Jp} + \frac{\mathrm{Lp}^2\,\mathrm{mp}}{4}\right\}\right\}$$

In[•]:=
```
C1 = {{1/4 Lp^2 mp Sin[2 α[t]] α'[t] + Br + n Kg^2 Kt km / Rm, 1/2 Lp Lr mp Sin[α[t]]},
  {-1/8 Lp^2 mp Sin[2 α[t]] θ'[t], Bp}}
```

Out[•]=
$$\left\{\left\{\mathrm{Br} + \frac{\mathrm{Kg}^2\,\mathrm{km}\,\mathrm{Kt}\,\mathrm{n}}{\mathrm{Rm}} + \frac{1}{4}\,\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[2\,\alpha[t]]\,\alpha'[t],\ \frac{1}{2}\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Sin}[\alpha[t]]\right\},\ \left\{-\frac{1}{8}\,\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[2\,\alpha[t]]\,\theta'[t],\ \mathrm{Bp}\right\}\right\}$$

In[•]:=
```
G = {0, -1/2 g Lp mp Sin[α[t]]}
```

Out[•]=
$$\left\{0, -\frac{1}{2}\, g\, Lp\, mp\, \text{Sin}[\alpha[t]]\right\}$$

In[•]:=
```
B = {n Kg Kt u[t] / Rm, 0}
```

Out[•]=
$$\left\{\frac{Kg\, Kt\, n\, u[t]}{Rm}, 0\right\}$$

In[•]:=
```
q = {θ[t], α[t]}
```

Out[•]=
$$\{\theta[t], \alpha[t]\}$$

In[•]:=
```
vecqdd = Inverse[H].( - C1.D[q, t] - G + B)  // Simplify
```

Out[•]=
$$\Big\{\big(2\, g\, Lp^2\, Lr\, mp^2\, Rm\, \text{Sin}[2\,\alpha[t]] + 4\, Kg\, Kt\, \left(4\, Jp + Lp^2\, mp\right)\, n\, u[t] - 16\, Jp\, Kg^2\, km\, Kt\, n\, \theta'[t] - 4\, Kg^2\, km\, Kt\, Lp^2\, mp\, n\, \theta'[t] - 16\, Br\, Jp\, Rm\, \theta'[t] - 4\, Br\, Lp^2\, mp\, Rm\, \theta'[t] + Lp^3\, Lr\, mp^2\, Rm\, \text{Cos}[\alpha[t]]\, \text{Sin}[2\,\alpha[t]]\, \theta'[t]^2 - Lp\, mp\, Rm\, \alpha'[t]\, \left(8\, Bp\, Lr\, \text{Cos}[\alpha[t]] + 2\, Lr\, \left(4\, Jp + Lp^2\, mp\right)\, \text{Sin}[\alpha[t]] + Lp\, \left(4\, Jp + Lp^2\, mp\right)\, \text{Sin}[2\,\alpha[t]]\, \theta'[t]\right)\big) \Big/ \left(Rm\, \left(-4\, Lp^2\, Lr^2\, mp^2\, \text{Cos}[\alpha[t]]^2 + \left(4\, Jp + Lp^2\, mp\right)\, \left(4\, \left(Jr + Lr^2\, mp\right) + Lp^2\, mp\, \text{Sin}[\alpha[t]]^2\right)\right)\right),$$
$$\big(8\, Kg\, Kt\, Lp\, Lr\, mp\, n\, \text{Cos}[\alpha[t]]\, u[t] - 2\, Rm\, \alpha'[t]\, \left(8\, Bp\, Jr + 8\, Bp\, Lr^2\, mp + 2\, Bp\, Lp^2\, mp\, \text{Sin}[\alpha[t]]^2 + Lp^2\, Lr^2\, mp^2\, \text{Sin}[2\,\alpha[t]] + 2\, Lp^3\, Lr\, mp^2\, \text{Cos}[\alpha[t]]^2\, \text{Sin}[\alpha[t]]\, \theta'[t]\right) + Lp\, mp\, \left(2\, g\, Rm\, \text{Sin}[\alpha[t]]\, \left(4\, \left(Jr + Lr^2\, mp\right) + Lp^2\, mp\, \text{Sin}[\alpha[t]]^2\right) - 8\, Lr\, \left(Kg^2\, km\, Kt\, n + Br\, Rm\right)\, \text{Cos}[\alpha[t]]\, \theta'[t] + Lp\, Rm\, \left(Lp^2\, mp\, \text{Cos}[\alpha[t]]\, \text{Sin}[\alpha[t]]^3 + 2\, \left(Jr + Lr^2\, mp\right)\, \text{Sin}[2\,\alpha[t]]\right)\, \theta'[t]^2\right)\big) \Big/ \left(Rm\, \left(-4\, Lp^2\, Lr^2\, mp^2\, \text{Cos}[\alpha[t]]^2 + \left(4\, Jp + Lp^2\, mp\right)\, \left(4\, \left(Jr + Lr^2\, mp\right) + Lp^2\, mp\, \text{Sin}[\alpha[t]]^2\right)\right)\right)\Big\}$$

In[•]:=
```
fstate = {θ'[t], α'[t], vecqdd[[1]], vecqdd[[2]]} /.
  {θ[t] → x1, α[t] → x2, θ'[t] → x3, α'[t] → x4}
```

Out[•]=
$$\Big\{x_3, x_4, \big(2\, g\, Lp^2\, Lr\, mp^2\, Rm\, \text{Sin}[2\, x_2] - 16\, Jp\, Kg^2\, km\, Kt\, n\, x_3 - 4\, Kg^2\, km\, Kt\, Lp^2\, mp\, n\, x_3 - 16\, Br\, Jp\, Rm\, x_3 - 4\, Br\, Lp^2\, mp\, Rm\, x_3 + Lp^3\, Lr\, mp^2\, Rm\, \text{Cos}[x_2]\, \text{Sin}[2\, x_2]\, x_3^2 - Lp\, mp\, Rm\, \left(8\, Bp\, Lr\, \text{Cos}[x_2] + 2\, Lr\, \left(4\, Jp + Lp^2\, mp\right)\, \text{Sin}[x_2] + Lp\, \left(4\, Jp + Lp^2\, mp\right)\, \text{Sin}[2\, x_2]\, x_3\right)\, x_4 + 4\, Kg\, Kt\, \left(4\, Jp + Lp^2\, mp\right)\, n\, u[t]\big) \Big/ \left(Rm\, \left(-4\, Lp^2\, Lr^2\, mp^2\, \text{Cos}[x_2]^2 + \left(4\, Jp + Lp^2\, mp\right)\, \left(4\, \left(Jr + Lr^2\, mp\right) + Lp^2\, mp\, \text{Sin}[x_2]^2\right)\right)\right),$$
$$\big(Lp\, mp\, \left(2\, g\, Rm\, \text{Sin}[x_2]\, \left(4\, \left(Jr + Lr^2\, mp\right) + Lp^2\, mp\, \text{Sin}[x_2]^2\right) - 8\, Lr\, \left(Kg^2\, km\, Kt\, n + Br\, Rm\right)\, \text{Cos}[x_2]\, x_3 + Lp\, Rm\, \left(Lp^2\, mp\, \text{Cos}[x_2]\, \text{Sin}[x_2]^3 + 2\, \left(Jr + Lr^2\, mp\right)\, \text{Sin}[2\, x_2]\right)\, x_3^2\right) - 2\, Rm\, \left(8\, Bp\, Jr + 8\, Bp\, Lr^2\, mp + 2\, Bp\, Lp^2\, mp\, \text{Sin}[x_2]^2 + Lp^2\, Lr^2\, mp^2\, \text{Sin}[2\, x_2] + 2\, Lp^3\, Lr\, mp^2\, \text{Cos}[x_2]^2\, \text{Sin}[x_2]\, x_3\right)\, x_4 + 8\, Kg\, Kt\, Lp\, Lr\, mp\, n\, \text{Cos}[x_2]\, u[t]\big) \Big/ \left(Rm\, \left(-4\, Lp^2\, Lr^2\, mp^2\, \text{Cos}[x_2]^2 + \left(4\, Jp + Lp^2\, mp\right)\, \left(4\, \left(Jr + Lr^2\, mp\right) + Lp^2\, mp\, \text{Sin}[x_2]^2\right)\right)\right)\Big\}$$

In[•]:=
```
xvec = {x1, x2, x3, x4}
```

Out[•]=
$$\{x_1, x_2, x_3, x_4\}$$

In[ ]:=
```
D[fstate, {xvec}] /. {x1 → 0, x2 → 0, x3 → 0, x4 → 0, u → 0} // FullSimplify // MatrixForm
```

Out[ ]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{g\,Lp^2\,Lr\,mp^2}{Jr\,Lp^2\,mp+4\,Jp\,(Jr+Lr^2\,mp)} & -\frac{(4\,Jp+Lp^2\,mp)\,(Kg^2\,km\,Kt\,n+Br\,Rm)}{(Jr\,Lp^2\,mp+4\,Jp\,(Jr+Lr^2\,mp))\,Rm} & -\frac{2\,Bp\,Lp\,Lr\,mp}{Jr\,Lp^2\,mp+4\,Jp\,(Jr+Lr^2\,mp)} \\ 0 & \frac{2\,g\,Lp\,mp\,(Jr+Lr^2\,mp)}{Jr\,Lp^2\,mp+4\,Jp\,(Jr+Lr^2\,mp)} & -\frac{2\,Lp\,Lr\,mp\,(Kg^2\,km\,Kt\,n+Br\,Rm)}{(Jr\,Lp^2\,mp+4\,Jp\,(Jr+Lr^2\,mp))\,Rm} & -\frac{4\,Bp\,(Jr+Lr^2\,mp)}{Jr\,Lp^2\,mp+4\,Jp\,(Jr+Lr^2\,mp)} \end{pmatrix}$$

In[ ]:=
```
B2 =
 D[fstate, u[t]] /. {x1 → 0, x2 → 0, x3 → 0, x4 → 0, u → 0} // FullSimplify // MatrixForm
```

Out[ ]//MatrixForm=

$$\begin{pmatrix} 0 \\ 0 \\ \frac{Kg\,Kt\,(4\,Jp+Lp^2\,mp)\,n}{(Jr\,Lp^2\,mp+4\,Jp\,(Jr+Lr^2\,mp))\,Rm} \\ \frac{2\,Kg\,Kt\,Lp\,Lr\,mp\,n}{4\,Jp\,Jr\,Rm+Jr\,Lp^2\,mp\,Rm+4\,Jp\,Lr^2\,mp\,Rm} \end{pmatrix}$$

In[•]:=
```
A = D[fstate, {xvec}] // FullSimplify
```

Out[•]=

$$\left\{\{0,\,0,\,1,\,0\},\ \{0,\,0,\,0,\,1\},\right.$$

$$\left\{0,\ \left(\mathrm{Lp}\,\mathrm{mp}\left(\frac{1}{2}\,\mathrm{Rm}\left(-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)\right)\right.\right.\right.$$
$$\left(\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\left(8\,\mathrm{g}\,\mathrm{Cos}[2\,x_2]+\mathrm{Lp}\left(\mathrm{Cos}[x_2]+3\,\mathrm{Cos}[3\,x_2]\right)x_3^2\right)+\right.$$
$$4\left(-\mathrm{Lr}\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\mathrm{Cos}[x_2]+4\,\mathrm{Bp}\,\mathrm{Lr}\,\mathrm{Sin}[x_2]-\mathrm{Lp}\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\mathrm{Cos}[2\,x_2]\,x_3\right)x_4-$$
$$\mathrm{Lp}\left(4\,\mathrm{Jp}+\left(\mathrm{Lp}^2+4\,\mathrm{Lr}^2\right)\mathrm{mp}\right)\mathrm{Sin}[2\,x_2]\left(\mathrm{Lp}^3\,\mathrm{Lr}\,\mathrm{mp}^2\,\mathrm{Rm}\,\mathrm{Cos}[x_2]\,\mathrm{Sin}[2\,x_2]\,x_3^2-2\,\mathrm{Lp}\,\mathrm{Lr}\right.$$
$$\mathrm{mp}\,\mathrm{Rm}\left(-\mathrm{g}\,\mathrm{Lp}\,\mathrm{mp}\,\mathrm{Sin}[2\,x_2]+\left(4\,\mathrm{Bp}\,\mathrm{Cos}[x_2]+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\mathrm{Sin}[x_2]\right)x_4\right)-\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)$$
$$\left.\left.\left.x_3\left(4\,\mathrm{Kg}^2\,\mathrm{km}\,\mathrm{Kt}\,\mathrm{n}+4\,\mathrm{Br}\,\mathrm{Rm}+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Rm}\,\mathrm{Sin}[2\,x_2]\,x_4\right)+4\,\mathrm{Kg}\,\mathrm{Kt}\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\mathrm{n}\,\mathrm{u}[\mathrm{t}]\right)\right)\right)\Big/$$
$$\left(\mathrm{Rm}\left(-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)\right)^2\right),$$
$$\frac{4\,\mathrm{Lp}^3\,\mathrm{Lr}\,\mathrm{mp}^2\,\mathrm{Rm}\,\mathrm{Cos}[x_2]^2\,\mathrm{Sin}[x_2]\,x_3-\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\,\mathrm{Kg}^2\,\mathrm{km}\,\mathrm{Kt}\,\mathrm{n}+4\,\mathrm{Br}\,\mathrm{Rm}+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Rm}\,\mathrm{Sin}[2\,x_2]\,x_4\right)}{\mathrm{Rm}\left(-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)\right)},$$
$$\left.-\frac{\mathrm{Lp}\,\mathrm{mp}\left(8\,\mathrm{Bp}\,\mathrm{Lr}\,\mathrm{Cos}[x_2]+2\,\mathrm{Lr}\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\mathrm{Sin}[x_2]+\mathrm{Lp}\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\mathrm{Sin}[2\,x_2]\,x_3\right)}{-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)}\right\},$$

$$\left\{0,\ \left(\mathrm{Lp}\,\mathrm{mp}\left(\left(-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)\right)\right.\right.\right.$$
$$\left(2\,\mathrm{g}\,\mathrm{Rm}\,\mathrm{Cos}[x_2]\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+3\,\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)+8\,\mathrm{Lr}\left(\mathrm{Kg}^2\,\mathrm{km}\,\mathrm{Kt}\,\mathrm{n}+\mathrm{Br}\,\mathrm{Rm}\right)\mathrm{Sin}[x_2]\,x_3+\right.$$
$$\frac{1}{2}\,\mathrm{Lp}\,\mathrm{Rm}\left(\left(8\,\mathrm{Jr}+\left(\mathrm{Lp}^2+8\,\mathrm{Lr}^2\right)\mathrm{mp}\right)\mathrm{Cos}[2\,x_2]-\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Cos}[4\,x_2]\right)x_3^2-$$
$$\mathrm{Lp}\,\mathrm{Rm}\left(4\left(\mathrm{Lr}^2\,\mathrm{mp}\,\mathrm{Cos}[2\,x_2]+\mathrm{Bp}\,\mathrm{Sin}[2\,x_2]\right)+\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\left(\mathrm{Cos}[x_2]+3\,\mathrm{Cos}[3\,x_2]\right)x_3\right)x_4-$$
$$\left.8\,\mathrm{Kg}\,\mathrm{Kt}\,\mathrm{Lr}\,\mathrm{n}\,\mathrm{Sin}[x_2]\,\mathrm{u}[\mathrm{t}]\right)-\mathrm{Lp}\left(4\,\mathrm{Jp}+\left(\mathrm{Lp}^2+4\,\mathrm{Lr}^2\right)\mathrm{mp}\right)\mathrm{Sin}[2\,x_2]$$
$$\left(\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Rm}\left(\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Cos}[x_2]\,\mathrm{Sin}[x_2]^3+2\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)\mathrm{Sin}[2\,x_2]\right)x_3^2-\right.$$
$$4\,\mathrm{Rm}\left(4\,\mathrm{Bp}\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]\left(\mathrm{Lr}^2\,\mathrm{mp}\,\mathrm{Cos}[x_2]+\mathrm{Bp}\,\mathrm{Sin}[x_2]\right)\right)x_4-$$
$$2\,\mathrm{Lp}\,\mathrm{Lr}\,\mathrm{mp}\,\mathrm{Cos}[x_2]\,x_3\left(4\,\mathrm{Kg}^2\,\mathrm{km}\,\mathrm{Kt}\,\mathrm{n}+4\,\mathrm{Br}\,\mathrm{Rm}+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Rm}\,\mathrm{Sin}[2\,x_2]\,x_4\right)+$$
$$\left.\left.\left.2\,\mathrm{Lp}\,\mathrm{mp}\left(\mathrm{g}\,\mathrm{Rm}\,\mathrm{Sin}[x_2]\left(4\,\mathrm{Jr}+4\,\mathrm{Lr}^2\,\mathrm{mp}+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)+4\,\mathrm{Kg}\,\mathrm{Kt}\,\mathrm{Lr}\,\mathrm{n}\,\mathrm{Cos}[x_2]\,\mathrm{u}[\mathrm{t}]\right)\right)\right)\Big/$$
$$\left(\mathrm{Rm}\left(-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)\right)^2\right),$$
$$\left(\mathrm{Lp}\,\mathrm{mp}\,\mathrm{Cos}[x_2]\left(\mathrm{Lp}\,\mathrm{Rm}\left(8\,\mathrm{Jr}+\mathrm{Lp}^2\,\mathrm{mp}+8\,\mathrm{Lr}^2\,\mathrm{mp}-\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Cos}[2\,x_2]\right)\mathrm{Sin}[x_2]\,x_3-\right.\right.$$
$$\left.\left.2\,\mathrm{Lr}\left(4\,\mathrm{Kg}^2\,\mathrm{km}\,\mathrm{Kt}\,\mathrm{n}+4\,\mathrm{Br}\,\mathrm{Rm}+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Rm}\,\mathrm{Sin}[2\,x_2]\,x_4\right)\right)\right)\Big/$$
$$\left(\mathrm{Rm}\left(-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)\right)\right)\right),$$
$$-\left(\left(4\left(4\,\mathrm{Bp}\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]\left(\mathrm{Lr}^2\,\mathrm{mp}\,\mathrm{Cos}[x_2]+\mathrm{Bp}\,\mathrm{Sin}[x_2]\right)+\right.\right.\right.$$
$$\left.\left.\left.\mathrm{Lp}^3\,\mathrm{Lr}\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2\,\mathrm{Sin}[x_2]\,x_3\right)\right)\Big/\left(-4\,\mathrm{Lp}^2\,\mathrm{Lr}^2\,\mathrm{mp}^2\,\mathrm{Cos}[x_2]^2+\left(4\,\mathrm{Jp}+\mathrm{Lp}^2\,\mathrm{mp}\right)\left(4\left(\mathrm{Jr}+\mathrm{Lr}^2\,\mathrm{mp}\right)+\mathrm{Lp}^2\,\mathrm{mp}\,\mathrm{Sin}[x_2]^2\right)\right)\right)\right\}\right\}$$

In[•]:=
```
A // ToMatlab
```

Out[•]=
```
[0,0,1,0;0,0,0,0,1;0,Lp.*mp.*Rm.^(-1).*((-4).*Lp.^2.*Lr.^2.*mp.^2.* ...
  cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*(4.*(Jr+Lr.^2.*mp)+ ...
  Lp.^2.*mp.*sin(Subscript(x,2)).^2)).^(-2).*((1/2).*Rm.*((-4).* ...
  Lp.^2.*Lr.^2.*mp.^2.*cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*( ...
  4.*(Jr+Lr.^2.*mp)+Lp.^2.*mp.*sin(Subscript(x,2)).^2)).*(Lp.*Lr.* ...
  mp.*(8.*g.*cos(2.*Subscript(x,2))+Lp.*(cos(Subscript(x,2))+3.*cos( ...
  3.*Subscript(x,2)))).*Subscript(x,3).^2)+4.*((-1).*Lr.*(4.*Jp+ ...
  Lp.^2.*mp).*cos(Subscript(x,2))+4.*Bp.*Lr.*sin(Subscript(x,2))+( ...
```

```
-1).*Lp.*(4.*Jp+Lp.^2.*mp).*cos(2.*Subscript(x,2)).*Subscript(x,3) ...
).*Subscript(x,4))+(-1).*Lp.*(4.*Jp+(Lp.^2+4.*Lr.^2).*mp).*sin(2.* ...
Subscript(x,2)).*(Lp.^3.*Lr.*mp.^2.*Rm.*cos(Subscript(x,2)).*sin( ...
2.*Subscript(x,2)).*Subscript(x,3).^2+(-2).*Lp.*Lr.*mp.*Rm.*((-1) ...
.*g.*Lp.*mp.*sin(2.*Subscript(x,2))+(4.*Bp.*cos(Subscript(x,2))+( ...
4.*Jp+Lp.^2.*mp).*sin(Subscript(x,2))).*Subscript(x,4))+(-1).*(4.* ...
Jp+Lp.^2.*mp).*Subscript(x,3).*(4.*Kg.^2.*km.*Kt.*n+4.*Br.*Rm+ ...
Lp.^2.*mp.*Rm.*sin(2.*Subscript(x,2)).*Subscript(x,4))+4.*Kg.*Kt.* ...
(4.*Jp+Lp.^2.*mp).*n.*u(t))),Rm.^(-1).*((-4).*Lp.^2.*Lr.^2.* ...
mp.^2.*cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*(4.*(Jr+Lr.^2.* ...
mp)+Lp.^2.*mp.*sin(Subscript(x,2)).^2)).^(-1).*(4.*Lp.^3.*Lr.* ...
mp.^2.*Rm.*cos(Subscript(x,2)).^2.*sin(Subscript(x,2)).*Subscript( ...
x,3)+(-1).*(4.*Jp+Lp.^2.*mp).*(4.*Kg.^2.*km.*Kt.*n+4.*Br.*Rm+ ...
Lp.^2.*mp.*Rm.*sin(2.*Subscript(x,2)).*Subscript(x,4))),(-1).*Lp.* ...
mp.*((-4).*Lp.^2.*Lr.^2.*mp.^2.*cos(Subscript(x,2)).^2+(4.*Jp+ ...
Lp.^2.*mp).*(4.*(Jr+Lr.^2.*mp)+Lp.^2.*mp.*sin(Subscript(x,2)).^2)) ...
.^(-1).*(8.*Bp.*Lr.*cos(Subscript(x,2))+2.*Lr.*(4.*Jp+Lp.^2.*mp).* ...
sin(Subscript(x,2))+Lp.*(4.*Jp+Lp.^2.*mp).*sin(2.*Subscript(x,2)) ...
.*Subscript(x,3));0,Lp.*mp.*Rm.^(-1).*((-4).*Lp.^2.*Lr.^2.*mp.^2.* ...
cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*(4.*(Jr+Lr.^2.*mp)+ ...
Lp.^2.*mp.*sin(Subscript(x,2)).^2)).^(-2).*(((-4).*Lp.^2.*Lr.^2.* ...
mp.^2.*cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*(4.*(Jr+Lr.^2.* ...
mp)+Lp.^2.*mp.*sin(Subscript(x,2)).^2)).*(2.*g.*Rm.*cos(Subscript( ...
x,2)).*(4.*(Jr+Lr.^2.*mp)+3.*Lp.^2.*mp.*sin(Subscript(x,2)).^2)+ ...
8.*Lr.*(Kg.^2.*km.*Kt.*n+Br.*Rm).*sin(Subscript(x,2)).*Subscript( ...
x,3)+(1/2).*Lp.*Rm.*((8.*Jr+(Lp.^2+8.*Lr.^2).*mp).*cos(2.* ...
Subscript(x,2))+(-1).*Lp.^2.*mp.*cos(4.*Subscript(x,2))).* ...
Subscript(x,3).^2+(-1).*Lp.*Rm.*(4.*(Lr.^2.*mp.*cos(2.*Subscript( ...
x,2))+Bp.*sin(2.*Subscript(x,2)))+Lp.*Lr.*mp.*(cos(Subscript(x,2)) ...
+3.*cos(3.*Subscript(x,2))).*Subscript(x,3)).*Subscript(x,4)+(-8) ...
.*Kg.*Kt.*Lr.*n.*sin(Subscript(x,2)).*u(t))+(-1).*Lp.*(4.*Jp+( ...
Lp.^2+4.*Lr.^2).*mp).*sin(2.*Subscript(x,2)).*(Lp.^2.*mp.*Rm.*( ...
Lp.^2.*mp.*cos(Subscript(x,2)).*sin(Subscript(x,2)).^3+2.*(Jr+ ...
Lr.^2.*mp).*sin(2.*Subscript(x,2))).*Subscript(x,3).^2+(-4).*Rm.*( ...
4.*Bp.*(Jr+Lr.^2.*mp)+Lp.^2.*mp.*sin(Subscript(x,2)).*(Lr.^2.*mp.* ...
cos(Subscript(x,2))+Bp.*sin(Subscript(x,2)))).*Subscript(x,4)+(-2) ...
.*Lp.*Lr.*mp.*cos(Subscript(x,2)).*Subscript(x,3).*(4.*Kg.^2.*km.* ...
Kt.*n+4.*Br.*Rm+Lp.^2.*mp.*Rm.*sin(2.*Subscript(x,2)).*Subscript( ...
x,4))+2.*Lp.*mp.*(g.*Rm.*sin(Subscript(x,2)).*(4.*Jr+4.*Lr.^2.*mp+ ...
Lp.^2.*mp.*sin(Subscript(x,2)).^2)+4.*Kg.*Kt.*Lr.*n.*cos( ...
Subscript(x,2)).*u(t))),Lp.*mp.*Rm.^(-1).*cos(Subscript(x,2)).*(( ...
-4).*Lp.^2.*Lr.^2.*mp.^2.*cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp) ...
.*(4.*(Jr+Lr.^2.*mp)+Lp.^2.*mp.*sin(Subscript(x,2)).^2)).^(-1).*( ...
Lp.*Rm.*(8.*Jr+Lp.^2.*mp+8.*Lr.^2.*mp+(-1).*Lp.^2.*mp.*cos(2.* ...
Subscript(x,2))).*sin(Subscript(x,2)).*Subscript(x,3)+(-2).*Lr.*( ...
4.*Kg.^2.*km.*Kt.*n+4.*Br.*Rm+Lp.^2.*mp.*Rm.*sin(2.*Subscript(x,2) ...
).*Subscript(x,4))),(-4).*((-4).*Lp.^2.*Lr.^2.*mp.^2.*cos( ...
Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*(4.*(Jr+Lr.^2.*mp)+Lp.^2.* ...
mp.*sin(Subscript(x,2)).^2)).^(-1).*(4.*Bp.*(Jr+Lr.^2.*mp)+Lp.^2.* ...
mp.*sin(Subscript(x,2)).*(Lr.^2.*mp.*cos(Subscript(x,2))+Bp.*sin( ...
Subscript(x,2)))+Lp.^3.*Lr.*mp.^2.*cos(Subscript(x,2)).^2.*sin( ...
```

```
Subscript(x,2)).*Subscript(x,3))];
```

In[•]:=
```
B3 = D[fstate, u[t]] // FullSimplify
```

Out[•]=
$$\left\{0,\ 0,\ \frac{4\,\text{Kg}\,\text{Kt}\,\left(4\,\text{Jp}+\text{Lp}^2\,\text{mp}\right)\,\text{n}}{\text{Rm}\,\left(-4\,\text{Lp}^2\,\text{Lr}^2\,\text{mp}^2\,\text{Cos}[x_2]^2+\left(4\,\text{Jp}+\text{Lp}^2\,\text{mp}\right)\,\left(4\,\left(\text{Jr}+\text{Lr}^2\,\text{mp}\right)+\text{Lp}^2\,\text{mp}\,\text{Sin}[x_2]^2\right)\right)},\right.$$
$$\left.\frac{8\,\text{Kg}\,\text{Kt}\,\text{Lp}\,\text{Lr}\,\text{mp}\,\text{n}\,\text{Cos}[x_2]}{\text{Rm}\,\left(-4\,\text{Lp}^2\,\text{Lr}^2\,\text{mp}^2\,\text{Cos}[x_2]^2+\left(4\,\text{Jp}+\text{Lp}^2\,\text{mp}\right)\,\left(4\,\left(\text{Jr}+\text{Lr}^2\,\text{mp}\right)+\text{Lp}^2\,\text{mp}\,\text{Sin}[x_2]^2\right)\right)}\right\}$$

In[•]:=
```
B3 // ToMatlab
```

Out[•]=
```
[0,0,4.*Kg.*Kt.*(4.*Jp+Lp.^2.*mp).*n.*Rm.^(-1).*((-4).*Lp.^2.* ...
  Lr.^2.*mp.^2.*cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*(4.*(Jr+ ...
  Lr.^2.*mp)+Lp.^2.*mp.*sin(Subscript(x,2)).^2)).^(-1),8.*Kg.*Kt.* ...
  Lp.*Lr.*mp.*n.*Rm.^(-1).*cos(Subscript(x,2)).*((-4).*Lp.^2.* ...
  Lr.^2.*mp.^2.*cos(Subscript(x,2)).^2+(4.*Jp+Lp.^2.*mp).*(4.*(Jr+ ...
  Lr.^2.*mp)+Lp.^2.*mp.*sin(Subscript(x,2)).^2)).^(-1)];
```

In[•]:=
```
Collect[Simplify[D[L, {q}], Trig → False] ,
  {θ''[t], θ'[t], α''[t], α'[t], α'[t] × θ'[t]}] // MatrixForm
```

Out[•]//MatrixForm=
$$\begin{pmatrix} 0 \\ \frac{1}{2}\,\text{g}\,\text{Lp}\,\text{mp}\,\text{Sin}[\alpha[t]]+\frac{1}{2}\,\text{Lp}\,\text{Lr}\,\text{mp}\,\text{Sin}[\alpha[t]]\,\alpha'[t]\,\theta'[t]+\frac{1}{4}\,\text{Lp}^2\,\text{mp}\,\text{Cos}[\alpha[t]]\,\text{Sin}[\alpha[t]]\,\theta'[t]^2 \end{pmatrix}$$