**EOM =**

$$\texttt{D}[\mathcal{X}, \{t, 2\}] == \left(\left(\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -\alpha \end{pmatrix} \left(1 - \frac{1}{A}\right)\right).\mathcal{V}_1 + \left(\kappa \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -\alpha \end{pmatrix} \left(1 - \frac{1}{B}\mathcal{L}\right)\right).\mathcal{V}_2 - \begin{pmatrix} 0 \\ \gamma \\ 0 \end{pmatrix} \text{ // Flatten;}$$

$$\{x_1[t] = y_1[t] = y_2[t] = 0,\ x_2[t] = 2\, w_p,\ \theta_p[t] \to 0\} : \left\{x_p[t] \to w_p,\ y_p[t] \to \frac{1}{2}\left(-2 - \gamma - 2\, h_p\right)\right\}$$

**perturbations :**

In[385]:= $\texttt{EquilibiumPoinit} = \left\{\theta_{p0} \to 0,\ x_{p0} \to w_p,\ y_{p0} \to -\left(\frac{1}{2}\gamma + h_p + 1\right)\right\}$

$\texttt{GivenEquibPoints} = \{x_1[t] \to 0,\ y_1[t] \to 0,\ y_2[t] \to 0,\ x_2[t] \to 2\, w_p\}$

```
perturb = {
  θp[t] → θp0 + δθ[t],
  xp[t] → xp0 + δx[t],
  yp[t] → yp0 + δy[t]
 }
perturbD2 = {
  D[θp[t], {t, 2}] → D[δθ[t], {t, 2}],
  D[xp[t], {t, 2}] → D[δx[t], {t, 2}],
  D[yp[t], {t, 2}] → D[δy[t], {t, 2}]
 }
```

Out[385]= $\left\{\theta_{p0} \to 0,\ x_{p0} \to w_p,\ y_{p0} \to -1 - \frac{\gamma}{2} - h_p\right\}$

Out[386]= $\{x_1[t] \to 0,\ y_1[t] \to 0,\ y_2[t] \to 0,\ x_2[t] \to 2\, w_p\}$

Out[387]= $\{\theta_p[t] \to \theta_{p0} + \delta\theta[t],\ x_p[t] \to x_{p0} + \delta x[t],\ y_p[t] \to y_{p0} + \delta y[t]\}$

Out[388]= $\{\theta_p''[t] \to \delta\theta''[t],\ x_p''[t] \to \delta x''[t],\ y_p''[t] \to \delta y''[t]\}$

In[286]:= **Aw = A /. nameChange**

Out[286]= $\sqrt{\left((\text{Sin}[\theta_p[t]]\, h_p + \text{Cos}[\theta_p[t]]\, w_p + x_1[t] - x_p[t])^2 + (-\text{Cos}[\theta_p[t]]\, h_p + \text{Sin}[\theta_p[t]]\, w_p + y_1[t] - y_p[t])^2\right)}$

In[320]:= **Bw = B /. nameChange**

Out[320]= $\sqrt{\left((\text{Sin}[\theta_p[t]]\, h_p - \text{Cos}[\theta_p[t]]\, w_p + x_2[t] - x_p[t])^2 + (-\text{Cos}[\theta_p[t]]\, h_p - \text{Sin}[\theta_p[t]]\, w_p + y_2[t] - y_p[t])^2\right)}$

In[343]:= **smallAngleRule = {Cos[δθ[t]] → 1, Sin[δθ[t]] -> δθ[t]}**

Out[343]= $\{\text{Cos}[\delta\theta[t]] \to 1,\ \text{Sin}[\delta\theta[t]] \to \delta\theta[t]\}$

In[425]:=
```
(v1 = 𝒱1 /. nameChange /. perturb /. EquilibiumPoinit /. smallAngleRule) //
  TraditionalForm
(v2 = 𝒱2 /. nameChange /. perturb /. EquilibiumPoinit /. smallAngleRule) //
  TraditionalForm
```

Out[425]//TraditionalForm=

$$\begin{pmatrix} -\delta x(t) + h_p\,\delta\theta(t) + x_1(t) \\ \frac{\gamma}{2} - \delta y(t) + w_p\,\delta\theta(t) + y_1(t) + 1 \\ w_p\left(\frac{\gamma}{2} + h_p - \delta y(t) - \delta\theta(t)\,(-w_p - \delta x(t) + x_1(t)) + y_1(t) + 1\right) + h_p\left(-w_p - \delta x(t) + x_1(t) + \delta\theta(t)\left(\frac{\gamma}{2} + h_p - \delta y(t) + y_1(t) + 1\right)\right) \end{pmatrix}$$

Out[426]//TraditionalForm=

$$\begin{pmatrix} -2\,w_p - \delta x(t) + h_p\,\delta\theta(t) + x_2(t) \\ \frac{\gamma}{2} - \delta y(t) - w_p\,\delta\theta(t) + y_2(t) + 1 \\ w_p\left(-\frac{\gamma}{2} - h_p + \delta y(t) + \delta\theta(t)\,(-w_p - \delta x(t) + x_2(t)) - y_2(t) - 1\right) + h_p\left(-w_p - \delta x(t) + x_2(t) + \delta\theta(t)\left(\frac{\gamma}{2} + h_p - \delta y(t) + y_2(t) + 1\right)\right) \end{pmatrix}$$

In[427]:=
```
v1 /. GivenEquibPoints // Simplify
v2 /. GivenEquibPoints // Simplify
```

Out[427]=

$$\left\{\{-\delta x[t] + h_p\,\delta\theta[t]\},\ \left\{1 + \frac{\gamma}{2} - \delta y[t] + w_p\,\delta\theta[t]\right\},\ \left\{\frac{1}{2}\left(2\,w_p^2\,\delta\theta[t] + w_p\,(2 + \gamma - 2\,\delta y[t] + 2\,\delta x[t]\,\delta\theta[t]) + h_p\,(-2\,\delta x[t] + (2 + \gamma + 2\,h_p - 2\,\delta y[t])\,\delta\theta[t])\right)\right\}\right\}$$

Out[428]=

$$\left\{\{-\delta x[t] + h_p\,\delta\theta[t]\},\ \left\{\frac{1}{2}\,(2 + \gamma - 2\,\delta y[t] - 2\,w_p\,\delta\theta[t])\right\},\ \left\{w_p^2\,\delta\theta[t] - \frac{1}{2}\,w_p\,(2 + \gamma - 2\,\delta y[t] + 2\,\delta x[t]\,\delta\theta[t]) + \frac{1}{2}\,h_p\,(-2\,\delta x[t] + (2 + \gamma + 2\,h_p - 2\,\delta y[t])\,\delta\theta[t])\right\}\right\}$$

In[315]:=
```
(*D[Aw,xp[t]]
 D[Aw,yp[t]]
 D[Aw,θp[t]]*)
temp = {xp[t] -> xp0, yp[t] → yp0, θp[t] → θp0};
"derivatives of 'A' in the 0 point:"
D[Aw^2, xp[t]] /. temp /. EquilibiumPoinit
D[Aw^2, yp[t]] /. temp /. EquilibiumPoinit
D[Aw^2, θp[t]] /. temp /. EquilibiumPoinit
```

In[321]:=
```
"derivatives of 'B' in the 0 point:"
D[Bw^2, x_p[t]] /. temp /. EquilibiumPoinit
D[Bw^2, y_p[t]] /. temp /. EquilibiumPoinit
D[Bw^2, θ_p[t]] /. temp /. EquilibiumPoinit
```

Out[321]= derivatives of 'B' in the 0 point:

Out[322]= $-2\,(-2\,w_p + x_2[t])$

Out[323]= $-2\left(1 + \frac{\gamma}{2} + y_2[t]\right)$

Out[324]= $2\,h_p\,(-2\,w_p + x_2[t]) - 2\,w_p\left(1 + \frac{\gamma}{2} + y_2[t]\right)$

In[407]:= **n = 1; Ataylored = Series[Aw /. GivenEquibPoints, {$x_p$[t], $x_{p0}$, n}, {$y_p$[t], $y_{p0}$, n}, {$\theta_p$[t], $\theta_{p0}$, n}] /. EquilibiumPoinit**

Out[407]=
$$\left(\left(\left(\sqrt{\left(-1-\frac{\Upsilon}{2}-h_p\right)^2+2\left(-1-\frac{\Upsilon}{2}-h_p\right)h_p+h_p^2}-\frac{\left(\left(-1-\frac{\Upsilon}{2}-h_p\right)w_p+h_p\,w_p\right)\theta_p[t]}{\sqrt{\left(-1-\frac{\Upsilon}{2}-h_p\right)^2+2\left(-1-\frac{\Upsilon}{2}-h_p\right)h_p+h_p^2}}+O[\theta_p[t]]^2\right)+\left(\frac{-1-\frac{\Upsilon}{2}}{\sqrt{\left(-1-\frac{\Upsilon}{2}-h_p\right)^2+2\left(-1-\frac{\Upsilon}{2}-h_p\right)h_p+h_p^2}}+\left(-\frac{w_p}{\sqrt{\left(-1-\frac{\Upsilon}{2}-h_p\right)^2+2\left(-1-\frac{\Upsilon}{2}-h_p\right)h_p+h_p^2}}+\frac{\left(-1-\frac{\Upsilon}{2}\right)\left(\left(-1-\frac{\Upsilon}{2}-h_p\right)w_p+h_p\,w_p\right)}{\left(\left(-1-\frac{\Upsilon}{2}-h_p\right)^2+2\left(-1-\frac{\Upsilon}{2}-h_p\right)h_p+h_p^2\right)^{3/2}}\right)\theta_p[t]+O[\theta_p[t]]^2\right)\left(y_p[t]+1+\frac{\Upsilon}{2}+h_p\right)+O\left[y_p[t]+1+\frac{\Upsilon}{2}+h_p\right]^2\right)+\left(\left(-\frac{h_p\,\theta_p[t]}{\sqrt{\left(-1-\frac{\Upsilon}{2}-h_p\right)^2+2\left(-1-\frac{\Upsilon}{2}-h_p\right)h_p+h_p^2}}+O[\theta_p[t]]^2\right)+\left(\frac{\left(-1-\frac{\Upsilon}{2}\right)h_p\,\theta_p[t]}{\left(\left(-1-\frac{\Upsilon}{2}-h_p\right)^2+2\left(-1-\frac{\Upsilon}{2}-h_p\right)h_p+h_p^2\right)^{3/2}}+O[\theta_p[t]]^2\right)\left(y_p[t]+1+\frac{\Upsilon}{2}+h_p\right)+O\left[y_p[t]+1+\frac{\Upsilon}{2}+h_p\right]^2\right)(x_p[t]-w_p)+O[x_p[t]-w_p]^2$$

In[411]:= **perturb**

Out[411]= $\{\theta_p[t]\to\theta_{p0}+\delta\theta[t],\ x_p[t]\to x_{p0}+\delta x[t],\ y_p[t]\to y_{p0}+\delta y[t]\}$

In[326]:= **n = 1; Series[Bw, {$x_p$[t], $x_{p0}$, n}, {$y_p$[t], $y_{p0}$, n}, {$\theta_p$[t], $\theta_{p0}$, n}] /. EquilibiumPoinit**

In[367]:= 

```
% // Simplify // TraditionalForm
```

Out[367]//TraditionalForm=

$$\left(\left(\frac{1}{2}\sqrt{(\gamma+2)^2}+\frac{(\gamma+2)\,w_p\,\theta_p(t)}{\sqrt{(\gamma+2)^2}}+O\!\left(\theta_p(t)^2\right)\right)+\left(\frac{\gamma}{2}+h_p+y_p(t)+1\right)\left(\frac{-\gamma-2}{\sqrt{(\gamma+2)^2}}+O\!\left(\theta_p(t)^2\right)\right)+O\!\left(\left(\frac{\gamma}{2}+h_p+y_p(t)+1\right)^2\right)\right)+(x_p(t)-w_p)\left(\left(-\frac{2\,h_p\,\theta_p(t)}{\sqrt{(\gamma+2)^2}}+O\!\left(\theta_p(t)^2\right)\right)+\left(-\frac{4\,h_p\,\theta_p(t)}{(\gamma+2)\sqrt{(\gamma+2)^2}}+O\!\left(\theta_p(t)^2\right)\right)\left(\frac{\gamma}{2}+h_p+y_p(t)+1\right)+O\!\left(\left(\frac{\gamma}{2}+h_p+y_p(t)+1\right)^2\right)\right)+O\!\left((x_p(t)-w_p)^2\right)$$

---

In[429]:= 

$$\textbf{Ataylored} = 1+\frac{\gamma}{2}-\delta y[t]+w\,\delta\theta[t]$$

$$\textbf{Btaylored} = 1+\frac{\gamma}{2}-\delta y[t]-w\,\delta\theta[t]$$

$$\mathcal{V}\textbf{taylored}_1 = \textbf{v1 /. GivenEquibPoints}$$

$$\mathcal{V}\textbf{taylored}_2 = \textbf{v2 /. GivenEquibPoints}$$

Out[429]= $1+\frac{\gamma}{2}-\delta y[t]+w\,\delta\theta[t]$

Out[430]= $1+\frac{\gamma}{2}-\delta y[t]-w\,\delta\theta[t]$

Out[431]= $\left\{\{-\delta x[t]+h_p\,\delta\theta[t]\},\ \left\{1+\frac{\gamma}{2}-\delta y[t]+w_p\,\delta\theta[t]\right\},\ \left\{w_p\left(1+\frac{\gamma}{2}+h_p-\delta y[t]-(-w_p-\delta x[t])\,\delta\theta[t]\right)+h_p\left(-w_p-\delta x[t]+\left(1+\frac{\gamma}{2}+h_p-\delta y[t]\right)\delta\theta[t]\right)\right\}\right\}$

Out[432]= $\left\{\{-\delta x[t]+h_p\,\delta\theta[t]\},\ \left\{1+\frac{\gamma}{2}-\delta y[t]-w_p\,\delta\theta[t]\right\},\ \left\{w_p\left(-1-\frac{\gamma}{2}-h_p+\delta y[t]+(w_p-\delta x[t])\,\delta\theta[t]\right)+h_p\left(w_p-\delta x[t]+\left(1+\frac{\gamma}{2}+h_p-\delta y[t]\right)\delta\theta[t]\right)\right\}\right\}$

---

In[390]:=
```
EOM(*=D[𝒳,{t,2}]==((1 0 0; 0 1 0; 0 0 -α) (1-1/A)).𝒱1+(κ(1 0 0; 0 1 0; 0 0 -α) (1-1/B ℒ)).𝒱2-(0; γ; 0)*)
  (*/.perturbD2*) // TraditionalForm
```

Out[390]//TraditionalForm=

$$\begin{pmatrix} x_p''(t) \\ y_p''(t) \\ \theta_p''(t) \end{pmatrix} = \left( \begin{array}{r} (\sin(\theta_p(t))\,h_p + \cos(\theta_p(t))\,l_p + x_1(t) - x_p(t)) \\ -\gamma + \left(1 - \frac{1}{\sqrt{(\sin(\theta_p(t))\,h_p + \cos(\theta_p(t))\,l_p + x_1(t) - x_p(t))^2 + (-\cos}} \right. \\ -\alpha\,(l_p\,(\cos(\theta_p(t))\,(y_1(t) - y_p(t)) - \sin(\theta_p(t))\,(x_1(t) - x_p(t))) + h_p\,(\cos(\theta_p(t))\,(x_1(t) - x_p(t)) + \sin(\theta_p(t))\,(y_1(t) - y_p(t))) \end{array} \right.$$

```
(*(EOMrephrase=D[𝒳,{t,2}]==(((1 0 0; 0 1 0; 0 0 -α) ((A-1)/A)).𝒱1+(κ(1 0 0; 0 1 0; 0 0 -α) ((B-ℒ)/B)).𝒱2-(0; γ; 0)
   (*//Flatten*))//Simplify//TraditionalForm*)
```

In[433]:=
```
(EOMrephrase = D[𝒳, {t, 2}] A B ==
   B ((1 0 0; 0 1 0; 0 0 -α) (A - 1)).𝒱1 + A (κ (1 0 0; 0 1 0; 0 0 -α) (B - ℒ)).𝒱2 - A B (0; γ; 0)) // TraditionalForm
```

Out[433]//TraditionalForm=

$$\left( \begin{array}{l} \sqrt{(\sin(\theta_p(t))\,h_p + \cos(\theta_p(t))\,l_p + x_1(t) - x_p(t))^2 + (-\cos(\theta_p(t))\,h_p + \sin(\theta_p(t))\,l_p + y_1(t) - y_p(t))^2}\ \sqrt{(\sin(\theta_p(t))\,h_p - \cos(\theta_p(t))\,l_p} \\ \sqrt{(\sin(\theta_p(t))\,h_p + \cos(\theta_p(t))\,l_p + x_1(t) - x_p(t))^2 + (-\cos(\theta_p(t))\,h_p + \sin(\theta_p(t))\,l_p + y_1(t) - y_p(t))^2}\ \sqrt{(\sin(\theta_p(t))\,h_p - \cos(\theta_p(t))\,l_p} \\ \sqrt{(\sin(\theta_p(t))\,h_p + \cos(\theta_p(t))\,l_p + x_1(t) - x_p(t))^2 + (-\cos(\theta_p(t))\,h_p + \sin(\theta_p(t))\,l_p + y_1(t) - y_p(t))^2}\ \sqrt{(\sin(\theta_p(t))\,h_p - \cos(\theta_p(t))\,l_p} \end{array} \right.$$

In[435]:=
```
(EOMLinearized = D[𝒳, {t, 2}] Ataylored Btaylored ==
    (Btaylored (1 0 0; 0 1 0; 0 0 -α) (Ataylored - 1)).𝒱taylored1 +
     (Ataylored κ (1 0 0; 0 1 0; 0 0 -α) (Btaylored - ℒ)).𝒱taylored2 -
    Ataylored Btaylored (0; γ; 0)) // TraditionalForm
```

Out[435]//TraditionalForm=

$$\begin{pmatrix} \left(\frac{\gamma}{2} - \delta y(t) - w\,\delta\theta(t) + 1\right)\left(\frac{\gamma}{2} - \delta y(t) + w\,\delta\theta(t) + 1\right) x_p''(t) \\ \left(\frac{\gamma}{2} - \delta y(t) - w\,\delta\theta(t) + 1\right)\left(\frac{\gamma}{2} - \delta y(t) + w\,\delta\theta(t) + 1\right) y_p''(t) \\ \left(\frac{\gamma}{2} - \delta y(t) - w\,\delta\theta(t) + 1\right)\left(\frac{\gamma}{2} - \delta y(t) + w\,\delta\theta(t) + 1\right) \theta_p''(t) \end{pmatrix} = \left( \begin{array}{r} \\ -\gamma\left(\frac{\gamma}{2} - \delta y(t) - w\,\delta\theta(t \right. \\ -\alpha\left(\frac{\gamma}{2} - \delta y(t) - w\,\delta\theta(t) + 1\right)\left(\frac{\gamma}{2} - \delta y(t) + w\,\delta\theta(t)\right)\left(w_p\left(\frac{\gamma}{2} + h_p - \right.\right. \end{array} \right.$$

In[441]:= **EOMLinearized // Expand(*//TraditionalForm*)**

Out[441]=

$$\Big\{\Big\{x_p''[t] + \gamma\, x_p''[t] + \frac{1}{4}\gamma^2\, x_p''[t] - 2\,\delta y[t]\, x_p''[t] - \gamma\,\delta y[t]\, x_p''[t] + \delta y[t]^2\, x_p''[t] - w^2\,\delta\theta[t]^2\, x_p''[t]\Big\},$$

$$\Big\{y_p''[t] + \gamma\, y_p''[t] + \frac{1}{4}\gamma^2\, y_p''[t] - 2\,\delta y[t]\, y_p''[t] - \gamma\,\delta y[t]\, y_p''[t] + \delta y[t]^2\, y_p''[t] - w^2\,\delta\theta[t]^2\, y_p''[t]\Big\},\ \Big\{\theta_p''[t] + \gamma\,\theta_p''[t] + \frac{1}{4}\gamma^2\,\theta_p''[t] - 2\,\delta y[t]\,\theta_p''[t] - \gamma\,\delta y[t]\,\theta_p''[t] + \delta y[t]^2\,\theta_p''[t] - w^2\,\delta\theta[t]^2\,\theta_p''[t]\Big\}\Big\} ==$$

$$\Big\{\Big\{-\frac{1}{2}\gamma\,\delta x[t] - \frac{1}{4}\gamma^2\,\delta x[t] - \kappa\,\delta x[t] + \mathcal{L}\,\kappa\,\delta x[t] - \gamma\,\kappa\,\delta x[t] + \frac{1}{2}\mathcal{L}\,\gamma\,\kappa\,\delta x[t] - \frac{1}{4}\gamma^2\,\kappa\,\delta x[t] +$$
$$\delta x[t]\,\delta y[t] + \gamma\,\delta x[t]\,\delta y[t] + 2\,\kappa\,\delta x[t]\,\delta y[t] - \mathcal{L}\,\kappa\,\delta x[t]\,\delta y[t] + \gamma\,\kappa\,\delta x[t]\,\delta y[t] -$$
$$\delta x[t]\,\delta y[t]^2 - \kappa\,\delta x[t]\,\delta y[t]^2 + \frac{1}{2}\gamma\, h_p\,\delta\theta[t] + \frac{1}{4}\gamma^2\, h_p\,\delta\theta[t] + \kappa\, h_p\,\delta\theta[t] -$$
$$\mathcal{L}\,\kappa\, h_p\,\delta\theta[t] + \gamma\,\kappa\, h_p\,\delta\theta[t] - \frac{1}{2}\mathcal{L}\,\gamma\,\kappa\, h_p\,\delta\theta[t] + \frac{1}{4}\gamma^2\,\kappa\, h_p\,\delta\theta[t] - w\,\delta x[t]\,\delta\theta[t] +$$
$$w\,\mathcal{L}\,\kappa\,\delta x[t]\,\delta\theta[t] - h_p\,\delta y[t]\,\delta\theta[t] - \gamma\, h_p\,\delta y[t]\,\delta\theta[t] - 2\,\kappa\, h_p\,\delta y[t]\,\delta\theta[t] +$$
$$\mathcal{L}\,\kappa\, h_p\,\delta y[t]\,\delta\theta[t] - \gamma\,\kappa\, h_p\,\delta y[t]\,\delta\theta[t] + h_p\,\delta y[t]^2\,\delta\theta[t] + \kappa\, h_p\,\delta y[t]^2\,\delta\theta[t] + w\, h_p\,\delta\theta[t]^2 -$$
$$w\,\mathcal{L}\,\kappa\, h_p\,\delta\theta[t]^2 + w^2\,\delta x[t]\,\delta\theta[t]^2 + w^2\,\kappa\,\delta x[t]\,\delta\theta[t]^2 - w^2\, h_p\,\delta\theta[t]^3 - w^2\,\kappa\, h_p\,\delta\theta[t]^3\Big\},$$

$$\Big\{-\frac{\gamma}{2} - \frac{\gamma^2}{2} - \frac{\gamma^3}{8} + \kappa - \mathcal{L}\,\kappa + \frac{3\,\gamma\,\kappa}{2} - \mathcal{L}\,\gamma\,\kappa + \frac{3\,\gamma^2\,\kappa}{4} - \frac{1}{4}\mathcal{L}\,\gamma^2\,\kappa + \frac{\gamma^3\,\kappa}{8} - \delta y[t] + \frac{1}{4}\gamma^2\,\delta y[t] -$$
$$3\,\kappa\,\delta y[t] + 2\,\mathcal{L}\,\kappa\,\delta y[t] - 3\,\gamma\,\kappa\,\delta y[t] + \mathcal{L}\,\gamma\,\kappa\,\delta y[t] - \frac{3}{4}\gamma^2\,\kappa\,\delta y[t] + 2\,\delta y[t]^2 +$$
$$\frac{1}{2}\gamma\,\delta y[t]^2 + 3\,\kappa\,\delta y[t]^2 - \mathcal{L}\,\kappa\,\delta y[t]^2 + \frac{3}{2}\gamma\,\kappa\,\delta y[t]^2 - \delta y[t]^3 - \kappa\,\delta y[t]^3 + w\,\delta\theta[t] +$$
$$\frac{1}{2}w\,\gamma\,\delta\theta[t] - w\,\mathcal{L}\,\kappa\,\delta\theta[t] - \frac{1}{2}w\,\mathcal{L}\,\gamma\,\kappa\,\delta\theta[t] + \frac{1}{2}\gamma\, w_p\,\delta\theta[t] + \frac{1}{4}\gamma^2\, w_p\,\delta\theta[t] - \kappa\, w_p\,\delta\theta[t] +$$
$$\mathcal{L}\,\kappa\, w_p\,\delta\theta[t] - \gamma\,\kappa\, w_p\,\delta\theta[t] + \frac{1}{2}\mathcal{L}\,\gamma\,\kappa\, w_p\,\delta\theta[t] - \frac{1}{4}\gamma^2\,\kappa\, w_p\,\delta\theta[t] - w\,\delta y[t]\,\delta\theta[t] +$$
$$w\,\mathcal{L}\,\kappa\,\delta y[t]\,\delta\theta[t] - w_p\,\delta y[t]\,\delta\theta[t] - \gamma\, w_p\,\delta y[t]\,\delta\theta[t] + 2\,\kappa\, w_p\,\delta y[t]\,\delta\theta[t] -$$
$$\mathcal{L}\,\kappa\, w_p\,\delta y[t]\,\delta\theta[t] + \gamma\,\kappa\, w_p\,\delta y[t]\,\delta\theta[t] + w_p\,\delta y[t]^2\,\delta\theta[t] - \kappa\, w_p\,\delta y[t]^2\,\delta\theta[t] -$$
$$w^2\,\delta\theta[t]^2 + \frac{1}{2}w^2\,\gamma\,\delta\theta[t]^2 - w^2\,\kappa\,\delta\theta[t]^2 - \frac{1}{2}w^2\,\gamma\,\kappa\,\delta\theta[t]^2 + w\, w_p\,\delta\theta[t]^2 +$$
$$w\,\mathcal{L}\,\kappa\, w_p\,\delta\theta[t]^2 + w^2\,\delta y[t]\,\delta\theta[t]^2 + w^2\,\kappa\,\delta y[t]\,\delta\theta[t]^2 - w^2\, w_p\,\delta\theta[t]^3 + w^2\,\kappa\, w_p\,\delta\theta[t]^3\Big\},$$

$$\Big\{-\frac{1}{2}\alpha\,\gamma\, w_p - \frac{1}{2}\alpha\,\gamma^2\, w_p - \frac{1}{8}\alpha\,\gamma^3\, w_p + \alpha\,\kappa\, w_p - \mathcal{L}\,\alpha\,\kappa\, w_p + \frac{3}{2}\alpha\,\gamma\,\kappa\, w_p - \mathcal{L}\,\alpha\,\gamma\,\kappa\, w_p + \frac{3}{4}\alpha\,\gamma^2\,\kappa\, w_p -$$
$$\frac{1}{4}\mathcal{L}\,\alpha\,\gamma^2\,\kappa\, w_p + \frac{1}{8}\alpha\,\gamma^3\,\kappa\, w_p + \frac{1}{2}\alpha\,\gamma\, h_p\,\delta x[t] + \frac{1}{4}\alpha\,\gamma^2\, h_p\,\delta x[t] + \alpha\,\kappa\, h_p\,\delta x[t] -$$
$$\mathcal{L}\,\alpha\,\kappa\, h_p\,\delta x[t] + \alpha\,\gamma\,\kappa\, h_p\,\delta x[t] - \frac{1}{2}\mathcal{L}\,\alpha\,\gamma\,\kappa\, h_p\,\delta x[t] + \frac{1}{4}\alpha\,\gamma^2\,\kappa\, h_p\,\delta x[t] + \alpha\, w_p\,\delta y[t] +$$
$$2\,\alpha\,\gamma\, w_p\,\delta y[t] + \frac{3}{4}\alpha\,\gamma^2\, w_p\,\delta y[t] - 3\,\alpha\,\kappa\, w_p\,\delta y[t] + 2\,\mathcal{L}\,\alpha\,\kappa\, w_p\,\delta y[t] - 3\,\alpha\,\gamma\,\kappa\, w_p\,\delta y[t] +$$
$$\mathcal{L}\,\alpha\,\gamma\,\kappa\, w_p\,\delta y[t] - \frac{3}{4}\alpha\,\gamma^2\,\kappa\, w_p\,\delta y[t] - \alpha\, h_p\,\delta x[t]\,\delta y[t] - \alpha\,\gamma\, h_p\,\delta x[t]\,\delta y[t] -$$
$$2\,\alpha\,\kappa\, h_p\,\delta x[t]\,\delta y[t] + \mathcal{L}\,\alpha\,\kappa\, h_p\,\delta x[t]\,\delta y[t] - \alpha\,\gamma\,\kappa\, h_p\,\delta x[t]\,\delta y[t] - 2\,\alpha\, w_p\,\delta y[t]^2 -$$
$$\frac{3}{2}\alpha\,\gamma\, w_p\,\delta y[t]^2 + 3\,\alpha\,\kappa\, w_p\,\delta y[t]^2 - \mathcal{L}\,\alpha\,\kappa\, w_p\,\delta y[t]^2 + \frac{3}{2}\alpha\,\gamma\,\kappa\, w_p\,\delta y[t]^2 + \alpha\, h_p\,\delta x[t]\,\delta y[t]^2 +$$

$$\alpha \kappa h_p \delta x[t]\, \delta y[t]^2 + \alpha w_p \delta y[t]^3 - \alpha \kappa w_p \delta y[t]^3 - \frac{1}{2} \alpha \gamma h_p \delta\theta[t] - \frac{1}{2} \alpha \gamma^2 h_p \delta\theta[t] -$$
$$\frac{1}{8} \alpha \gamma^3 h_p \delta\theta[t] - \alpha \kappa h_p \delta\theta[t] + \mathcal{L} \alpha \kappa h_p \delta\theta[t] - \frac{3}{2} \alpha \gamma \kappa h_p \delta\theta[t] + \mathcal{L} \alpha \gamma \kappa h_p \delta\theta[t] -$$
$$\frac{3}{4} \alpha \gamma^2 \kappa h_p \delta\theta[t] + \frac{1}{4} \mathcal{L} \alpha \gamma^2 \kappa h_p \delta\theta[t] - \frac{1}{8} \alpha \gamma^3 \kappa h_p \delta\theta[t] - \frac{1}{2} \alpha \gamma h_p^2 \delta\theta[t] -$$
$$\frac{1}{4} \alpha \gamma^2 h_p^2 \delta\theta[t] - \alpha \kappa h_p^2 \delta\theta[t] + \mathcal{L} \alpha \kappa h_p^2 \delta\theta[t] - \alpha \gamma \kappa h_p^2 \delta\theta[t] + \frac{1}{2} \mathcal{L} \alpha \gamma \kappa h_p^2 \delta\theta[t] -$$
$$\frac{1}{4} \alpha \gamma^2 \kappa h_p^2 \delta\theta[t] - w \alpha w_p \delta\theta[t] - \frac{1}{2} w \alpha \gamma w_p \delta\theta[t] - w \mathcal{L} \alpha \kappa w_p \delta\theta[t] - \frac{1}{2} w \mathcal{L} \alpha \gamma \kappa w_p \delta\theta[t] -$$
$$\frac{1}{2} \alpha \gamma w_p^2 \delta\theta[t] - \frac{1}{4} \alpha \gamma^2 w_p^2 \delta\theta[t] - \alpha \kappa w_p^2 \delta\theta[t] + \mathcal{L} \alpha \kappa w_p^2 \delta\theta[t] - \alpha \gamma \kappa w_p^2 \delta\theta[t] +$$
$$\frac{1}{2} \mathcal{L} \alpha \gamma \kappa w_p^2 \delta\theta[t] - \frac{1}{4} \alpha \gamma^2 \kappa w_p^2 \delta\theta[t] + w \alpha h_p \delta x[t]\, \delta\theta[t] - w \mathcal{L} \alpha \kappa h_p \delta x[t]\, \delta\theta[t] -$$
$$\frac{1}{2} \alpha \gamma w_p \delta x[t]\, \delta\theta[t] - \frac{1}{4} \alpha \gamma^2 w_p \delta x[t]\, \delta\theta[t] + \alpha \kappa w_p \delta x[t]\, \delta\theta[t] - \mathcal{L} \alpha \kappa w_p \delta x[t]\, \delta\theta[t] +$$
$$\alpha \gamma \kappa w_p \delta x[t]\, \delta\theta[t] - \frac{1}{2} \mathcal{L} \alpha \gamma \kappa w_p \delta x[t]\, \delta\theta[t] + \frac{1}{4} \alpha \gamma^2 \kappa w_p \delta x[t]\, \delta\theta[t] +$$
$$\alpha h_p \delta y[t]\, \delta\theta[t] + 2 \alpha \gamma h_p \delta y[t]\, \delta\theta[t] + \frac{3}{4} \alpha \gamma^2 h_p \delta y[t]\, \delta\theta[t] + 3 \alpha \kappa h_p \delta y[t]\, \delta\theta[t] -$$
$$2 \mathcal{L} \alpha \kappa h_p \delta y[t]\, \delta\theta[t] + 3 \alpha \gamma \kappa h_p \delta y[t]\, \delta\theta[t] - \mathcal{L} \alpha \gamma \kappa h_p \delta y[t]\, \delta\theta[t] +$$
$$\frac{3}{4} \alpha \gamma^2 \kappa h_p \delta y[t]\, \delta\theta[t] + \alpha h_p^2 \delta y[t]\, \delta\theta[t] + \alpha \gamma h_p^2 \delta y[t]\, \delta\theta[t] + 2 \alpha \kappa h_p^2 \delta y[t]\, \delta\theta[t] -$$
$$\mathcal{L} \alpha \kappa h_p^2 \delta y[t]\, \delta\theta[t] + \alpha \gamma \kappa h_p^2 \delta y[t]\, \delta\theta[t] + w \alpha w_p \delta y[t]\, \delta\theta[t] + w \mathcal{L} \alpha \kappa w_p \delta y[t]\, \delta\theta[t] +$$
$$\alpha w_p^2 \delta y[t]\, \delta\theta[t] + \alpha \gamma w_p^2 \delta y[t]\, \delta\theta[t] + 2 \alpha \kappa w_p^2 \delta y[t]\, \delta\theta[t] - \mathcal{L} \alpha \kappa w_p^2 \delta y[t]\, \delta\theta[t] +$$
$$\alpha \gamma \kappa w_p^2 \delta y[t]\, \delta\theta[t] + \alpha w_p \delta x[t]\, \delta y[t]\, \delta\theta[t] + \alpha \gamma w_p \delta x[t]\, \delta y[t]\, \delta\theta[t] -$$
$$2 \alpha \kappa w_p \delta x[t]\, \delta y[t]\, \delta\theta[t] + \mathcal{L} \alpha \kappa w_p \delta x[t]\, \delta y[t]\, \delta\theta[t] - \alpha \gamma \kappa w_p \delta x[t]\, \delta y[t]\, \delta\theta[t] -$$
$$2 \alpha h_p \delta y[t]^2 \delta\theta[t] - \frac{3}{2} \alpha \gamma h_p \delta y[t]^2 \delta\theta[t] - 3 \alpha \kappa h_p \delta y[t]^2 \delta\theta[t] + \mathcal{L} \alpha \kappa h_p \delta y[t]^2 \delta\theta[t] -$$
$$\frac{3}{2} \alpha \gamma \kappa h_p \delta y[t]^2 \delta\theta[t] - \alpha h_p^2 \delta y[t]^2 \delta\theta[t] - \alpha \kappa h_p^2 \delta y[t]^2 \delta\theta[t] - \alpha w_p^2 \delta y[t]^2 \delta\theta[t] -$$
$$\alpha \kappa w_p^2 \delta y[t]^2 \delta\theta[t] - \alpha w_p \delta x[t]\, \delta y[t]^2 \delta\theta[t] + \alpha \kappa w_p \delta x[t]\, \delta y[t]^2 \delta\theta[t] +$$
$$\alpha h_p \delta y[t]^3 \delta\theta[t] + \alpha \kappa h_p \delta y[t]^3 \delta\theta[t] - w \alpha h_p \delta\theta[t]^2 - \frac{1}{2} w \alpha \gamma h_p \delta\theta[t]^2 +$$
$$w \mathcal{L} \alpha \kappa h_p \delta\theta[t]^2 + \frac{1}{2} w \mathcal{L} \alpha \gamma \kappa h_p \delta\theta[t]^2 - w \alpha h_p^2 \delta\theta[t]^2 + w \mathcal{L} \alpha \kappa h_p^2 \delta\theta[t]^2 + w^2 \alpha w_p \delta\theta[t]^2 +$$
$$\frac{1}{2} w^2 \alpha \gamma w_p \delta\theta[t]^2 - w^2 \alpha \kappa w_p \delta\theta[t]^2 - \frac{1}{2} w^2 \alpha \gamma \kappa w_p \delta\theta[t]^2 - w \alpha w_p^2 \delta\theta[t]^2 + w \mathcal{L} \alpha \kappa w_p^2 \delta\theta[t]^2 -$$
$$w^2 \alpha h_p \delta x[t]\, \delta\theta[t]^2 - w^2 \alpha \kappa h_p \delta x[t]\, \delta\theta[t]^2 - w \alpha w_p \delta x[t]\, \delta\theta[t]^2 - w \mathcal{L} \alpha \kappa w_p \delta x[t]\, \delta\theta[t]^2 +$$
$$w \alpha h_p \delta y[t]\, \delta\theta[t]^2 - w \mathcal{L} \alpha \kappa h_p \delta y[t]\, \delta\theta[t]^2 - w^2 \alpha w_p \delta y[t]\, \delta\theta[t]^2 + w^2 \alpha \kappa w_p \delta y[t]\, \delta\theta[t]^2 +$$
$$w^2 \alpha h_p \delta\theta[t]^3 + \frac{1}{2} w^2 \alpha \gamma h_p \delta\theta[t]^3 + w^2 \alpha \kappa h_p \delta\theta[t]^3 + \frac{1}{2} w^2 \alpha \gamma \kappa h_p \delta\theta[t]^3 +$$
$$w^2 \alpha h_p^2 \delta\theta[t]^3 + w^2 \alpha \kappa h_p^2 \delta\theta[t]^3 + w^2 \alpha w_p^2 \delta\theta[t]^3 + w^2 \alpha \kappa w_p^2 \delta\theta[t]^3 + w^2 \alpha w_p \delta x[t]\, \delta\theta[t]^3 -$$
$$w^2 \alpha \kappa w_p \delta x[t]\, \delta\theta[t]^3 - w^2 \alpha h_p \delta y[t]\, \delta\theta[t]^3 - w^2 \alpha \kappa h_p \delta y[t]\, \delta\theta[t]^3 \big\}\big\}$$

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(*EOMLinearized[[2]]-EOM[[2]]//Simplify//TraditionalForm*)
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(*EOMrephrase[[2]]-EOM[[2]]//Simplify//TraditionalForm*)
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Out[403]//TraditionalForm=

$$-\sqrt{(\sin(\theta_p(t))\,h_p + \cos(\theta_p(t))\,l_p + x_1(t) - x_p(t))^2 + (\cos(\theta_p(t))\,h_p - \sin(\theta_p(t))\,l_p - y_1(t) + y$$

$$\alpha\left((l_p\,(\cos(\theta_p(t))\,(y_1(t) - y_p(t)) - \sin(\theta_p(t))\,(x_1(t) - x_p(t))) + h_p\,(\cos(\theta_p(t))\,(x_1(t) - x_p(t)) + \sin(\theta_p(t))\,(y_1(t) - y_p(t))))\left(1 - \frac{}{\sqrt{(\sin(\theta}}\right.\right.$$