

$$\begin{aligned}
& -m_0 \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \\
& \quad \left(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \zeta_1'(t)^2 - \\
& m_0 \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right) \\
& \quad \left(\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) - R(t) \sin(\theta(t)) \right) \zeta_2'(t)^2 - \\
& M_{P1} \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) \\
& \quad \left(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) \zeta_{P1}'(t)^2 - \\
& M_{P2} \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \right) \\
& \quad \left(\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) - R(t) \sin(\theta(t)) \right) \zeta_{P2}'(t)^2 - \\
& m_0 \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \\
& \quad \left(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \chi_1'(t)^2 - \\
& m_0 \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right) \\
& \quad \left(\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) - R(t) \sin(\theta(t)) \right) \chi_2'(t)^2 - \\
& M_{P1} \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) \\
& \quad \left(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) \chi_{P1}'(t)^2 - \\
& M_{P2} \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \right) \\
& \quad \left(\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) - R(t) \sin(\theta(t)) \right) \chi_{P2}'(t)^2 + \\
& \left(\mu m_0 \left(2 \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right) \right. \right. \\
& \quad \left. \left(R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right) \right) + \\
& \quad 2 \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right) \\
& \quad \left. \left(\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) - R(t) \sin(\theta(t)) \right) \right) \right) /
\end{aligned}$$

$$\begin{aligned}
& \left(2 \left(\sin^2(\alpha(t)) \left(\frac{L_0}{2} + \eta_2(t) \right)^2 + \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right)^2 + \right. \\
& \quad \left. \left(R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right)^2 \right)^{3/2} + \\
& (\mu M_{P2} (2 (\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t))) \\
& \quad (R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t))) + \\
& \quad 2 (\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t))) (\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \\
& \quad (L_0 + \eta_2(t) + \eta_{P2}(t)) - R(t) \sin(\theta(t)))) / (2 (\sin^2(\alpha(t)) (L_0 + \eta_2(t) + \eta_{P2}(t))^2 + \\
& \quad (\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)))^2 + \\
& \quad (R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)))^2)^{3/2}) - \\
& \frac{1}{2} M_M (2 (-\sin(\theta(t)) R'(t) - \cos(\theta(t)) R(t) \theta'(t)) (\cos(\theta(t)) R'(t) - R(t) \sin(\theta(t)) \theta'(t)) + \\
& \quad 2 (\sin(\theta(t)) R'(t) + \cos(\theta(t)) R(t) \theta'(t)) (\cos(\theta(t)) R'(t) - R(t) \sin(\theta(t)) \theta'(t))) - \\
& \frac{1}{2} m_0 \left(2 \left(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) - \right. \right. \\
& \quad \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_1'(t) \right) \\
& \quad \left(-\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) - \cos(\theta(t)) R(t) \theta'(t) - \right. \\
& \quad \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_1'(t) \right) + \\
& \quad 2 \left(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) - \right. \\
& \quad \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_1'(t) \right) \\
& \quad \left(\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) + \cos(\theta(t)) R(t) \theta'(t) + \right. \\
& \quad \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_1'(t) \right) \Bigg) - \\
& \frac{1}{2} m_0 \left(2 \left(\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) + \right. \right.
\end{aligned}$$

$$\begin{aligned}
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \left(\theta'(t) + \psi'(t) \right) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_2'(t) \Bigg) \\
& \left(\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) + \cos(\theta(t)) R(t) \theta'(t) - \right. \\
& \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \left(\theta'(t) + \psi'(t) \right) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_2'(t) \right) + \\
& 2 \left(\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) + \right. \\
& \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \left(\theta'(t) + \psi'(t) \right) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_2'(t) \right) \\
& \left(-\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) - \cos(\theta(t)) R(t) \theta'(t) + \right. \\
& \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \left(\theta'(t) + \psi'(t) \right) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_2'(t) \right) \Bigg) - \\
& \frac{1}{2} M_{P1} \left(2 \left(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) - \right. \right. \\
& \left. R(t) \sin(\theta(t)) \theta'(t) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) + \right. \\
& \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \right) \\
& \left(-\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) - \right. \\
& \left. \cos(\theta(t)) R(t) \theta'(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) - \right. \\
& \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \right) + \\
& 2 \left(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) - \right. \\
& \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \right. \\
& \left. (\eta_1'(t) + \eta_{P1}'(t)) \right) \left(\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) + \right. \\
& \left. \cos(\theta(t)) R(t) \theta'(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) + \right. \\
& \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \right) \Bigg) - \\
& \frac{1}{2} M_{P2} \left(2 \left(\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) - \right. \right. \\
& \left. R(t) \sin(\theta(t)) \theta'(t) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) - \right. \\
& \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \right) \\
& \left(\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) + \right. \\
& \left. \cos(\theta(t)) R(t) \theta'(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) - \right. \\
& \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \right) + \\
& 2 \left(\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) - \right.
\end{aligned}$$

$$\begin{aligned}
& R(t) \sin(\theta(t)) \theta'(t) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) - \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \\
& (-\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) - \\
& \cos(\theta(t)) R(t) \theta'(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) + \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t))) + \\
& \frac{1}{2} M_M \left(2 \cos(\theta(t)) R'(t) (\sin(\theta(t)) R'(t) + \cos(\theta(t)) R(t) \theta'(t)) - \right. \\
& 2 R(t) \sin(\theta(t)) \theta'(t) (\sin(\theta(t)) R'(t) + \cos(\theta(t)) R(t) \theta'(t)) - \\
& 2 \sin(\theta(t)) R'(t) (\cos(\theta(t)) R'(t) - R(t) \sin(\theta(t)) \theta'(t)) - \\
& 2 \cos(\theta(t)) R(t) \theta'(t) (\cos(\theta(t)) R'(t) - R(t) \sin(\theta(t)) \theta'(t)) + \\
& 2 \cos(\theta(t)) R(t) (-R(t) \sin(\theta(t)) \theta'(t)^2 + 2 \cos(\theta(t)) R'(t) \theta'(t) + \\
& \sin(\theta(t)) R''(t) + \cos(\theta(t)) R(t) \theta''(t)) - 2 R(t) \sin(\theta(t)) \\
& \left. (-\cos(\theta(t)) R(t) \theta'(t)^2 - 2 \sin(\theta(t)) R'(t) \theta'(t) + \cos(\theta(t)) R''(t) - R(t) \sin(\theta(t)) \theta''(t)) \right) + \\
& 2 \left(\frac{i_{zM}}{2} + \frac{i_{zp1}}{2} + \frac{i_{zp2}}{2} + i_{zT} \right) (\theta''(t) + \psi''(t)) + \\
& \frac{1}{2} \\
& m_0 \\
& \left(2 \left(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) - \right. \right. \\
& \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_1'(t) \right) \\
& \left(-\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) - \cos(\theta(t)) R(t) \theta'(t) - \right. \\
& \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_1'(t) \right) + \\
& 2 \left(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) - \right. \\
& \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_1'(t) \right) \\
& \left(\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t) + \cos(\theta(t)) R(t) \theta'(t) + \right.
\end{aligned}$$

$$\begin{aligned}
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_1'(t) \Big) + \\
& 2 \left(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \\
& \left(-\cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t)^2 + 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \right. \\
& \quad \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) \alpha'(t) - 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \eta_1'(t) \alpha'(t) - \\
& \cos(\theta(t)) R(t) \theta'(t)^2 - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t))^2 - \\
& 2 \sin(\theta(t)) R'(t) \theta'(t) - 2 \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) \eta_1'(t) + \\
& \cos(\theta(t)) R''(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha''(t) - R(t) \sin(\theta(t)) \theta''(t) - \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta''(t) + \psi''(t)) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_1''(t) \Big) + \\
& 2 \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \\
& \left(-\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha'(t)^2 - 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \right. \\
& \quad \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t)) \alpha'(t) - 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_1'(t) \alpha'(t) - \\
& R(t) \sin(\theta(t)) \theta'(t)^2 - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta'(t) + \psi'(t))^2 + \\
& 2 \cos(\theta(t)) R'(t) \theta'(t) + 2 \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) \eta_1'(t) + \sin(\theta(t)) R''(t) - \\
& \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \alpha''(t) + \cos(\theta(t)) R(t) \theta''(t) + \cos(\alpha(t)) \\
& \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) (\theta''(t) + \psi''(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_1''(t) \Big) + \\
& \frac{1}{2} m_0 \left(2 \left(\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) + \right. \right. \\
& \quad \left. \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t)) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_2'(t) \right) \right)
\end{aligned}$$

$$\begin{aligned}
& \left(\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) + \cos(\theta(t)) R(t) \theta'(t) - \right. \\
& \quad \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_2'(t) \right) + \\
& 2 \left(\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t) + \right. \\
& \quad \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t)) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_2'(t) \right) \\
& \left(-\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t) - \cos(\theta(t)) R(t) \theta'(t) + \right. \\
& \quad \left. \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_2'(t) \right) + \\
& 2 \left(\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) - R(t) \sin(\theta(t)) \right) \\
& \left(\cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t)^2 - 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \right. \\
& \quad \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t)) \alpha'(t) + 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \eta_2'(t) \alpha'(t) - \\
& \quad \cos(\theta(t)) R(t) \theta'(t)^2 + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t))^2 - \\
& \quad 2 \sin(\theta(t)) R'(t) \theta'(t) + 2 \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) \eta_2'(t) + \\
& \quad \cos(\theta(t)) R''(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha''(t) - R(t) \sin(\theta(t)) \theta''(t) + \\
& \quad \left. \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta''(t) + \psi''(t)) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \eta_2''(t) \right) + \\
& 2 \left(\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \right) \\
& \left(\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha'(t)^2 + 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) \right. \\
& \quad \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t)) \alpha'(t) + 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_2'(t) \alpha'(t) - \\
& \quad \left. R(t) \sin(\theta(t)) \theta'(t)^2 + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta'(t) + \psi'(t))^2 + \right.
\end{aligned}$$

$$\begin{aligned}
& 2 \cos(\theta(t)) R'(t) \theta'(t) - 2 \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) \eta_2'(t) + \sin(\theta(t)) R''(t) + \\
& \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) \alpha''(t) + \cos(\theta(t)) R(t) \theta''(t) - \cos(\alpha(t)) \\
& \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_2(t) \right) (\theta''(t) + \psi''(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \eta_2''(t) \Big) + \\
& \frac{1}{2} M_{P1} \Big(2 \big(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) - \\
& R(t) \sin(\theta(t)) \theta'(t) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) + \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \big) \\
& \big(-\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) - \\
& \cos(\theta(t)) R(t) \theta'(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) - \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \big) + \\
& 2 \big(\cos(\theta(t)) R'(t) - \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) - \\
& R(t) \sin(\theta(t)) \theta'(t) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) + \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \big) \\
& \big(\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t) + \\
& \cos(\theta(t)) R(t) \theta'(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) + \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \big) + \\
& 2 \big(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \big) \\
& \big(-\cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t)^2 + \\
& 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) \alpha'(t) - \\
& 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (\eta_1'(t) + \eta_{P1}'(t)) \alpha'(t) - \cos(\theta(t)) R(t) \theta'(t)^2 - \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t))^2 - 2 \sin(\theta(t)) R'(t) \theta'(t) - \\
& 2 \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) (\eta_1'(t) + \eta_{P1}'(t)) + \cos(\theta(t)) R''(t) - \\
& \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha''(t) - R(t) \sin(\theta(t)) \theta''(t) - \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta''(t) + \psi''(t)) + \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_1''(t) + \eta_{P1}''(t)) \big) + \\
& 2 \big(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \big) \\
& \big(-\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha'(t)^2 - \\
& 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t)) \alpha'(t) - \\
& 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_1'(t) + \eta_{P1}'(t)) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t)^2 - \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta'(t) + \psi'(t))^2 + 2 \cos(\theta(t)) R'(t) \theta'(t) + \\
& 2 \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) (\eta_1'(t) + \eta_{P1}'(t)) + \sin(\theta(t)) R''(t) - \\
& \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \alpha''(t) + \cos(\theta(t)) R(t) \theta''(t) +
\end{aligned}$$

$$\begin{aligned}
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) (\theta''(t) + \psi''(t)) + \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_1''(t) + \eta_{P1}''(t)) \Big) + \\
& \frac{1}{2} M_{P2} \Big(2 (\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) - \\
& R(t) \sin(\theta(t)) \theta'(t) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) - \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \Big) \\
& (\sin(\theta(t)) R'(t) + \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) + \\
& \cos(\theta(t)) R(t) \theta'(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) - \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \Big) + \\
& 2 (\cos(\theta(t)) R'(t) + \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) - \\
& R(t) \sin(\theta(t)) \theta'(t) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) - \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \Big) \\
& (-\sin(\theta(t)) R'(t) - \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t) - \\
& \cos(\theta(t)) R(t) \theta'(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) + \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \Big) + \\
& 2 (\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) - R(t) \sin(\theta(t))) \\
& (\cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t)^2 - \\
& 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) \alpha'(t) + \\
& 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (\eta_2'(t) + \eta_{P2}'(t)) \alpha'(t) - \cos(\theta(t)) R(t) \theta'(t)^2 + \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t))^2 - 2 \sin(\theta(t)) R'(t) \theta'(t) + \\
& 2 \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) (\eta_2'(t) + \eta_{P2}'(t)) + \cos(\theta(t)) R''(t) + \\
& \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha''(t) - R(t) \sin(\theta(t)) \theta''(t) + \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta''(t) + \psi''(t)) - \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\eta_2''(t) + \eta_{P2}''(t)) \Big) + \\
& 2 (\cos(\theta(t)) R(t) - \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t))) \\
& (\cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha'(t)^2 + \\
& 2 \cos(\theta(t) + \psi(t)) \sin(\alpha(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t)) \alpha'(t) + \\
& 2 \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_2'(t) + \eta_{P2}'(t)) \alpha'(t) - R(t) \sin(\theta(t)) \theta'(t)^2 + \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta'(t) + \psi'(t))^2 + 2 \cos(\theta(t)) R'(t) \theta'(t) - \\
& 2 \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (\theta'(t) + \psi'(t)) (\eta_2'(t) + \eta_{P2}'(t)) + \sin(\theta(t)) R''(t) + \\
& \sin(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) \alpha''(t) + \cos(\theta(t)) R(t) \theta''(t) - \\
& \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_2(t) + \eta_{P2}(t)) (\theta''(t) + \psi''(t)) - \\
& \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (\eta_2''(t) + \eta_{P2}''(t)) \Big) +
\end{aligned}$$

$$\begin{aligned}
& \left(\mu m_0 \left(2 \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \right. \right. \\
& \quad \left. \left(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \right) + \\
& \quad 2 \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \\
& \quad \left. \left(R(t) \sin(\theta(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right) \right) \Bigg) / \\
& \left(2 \left(\sin^2(\alpha(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right)^2 + \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right)^2 + \right. \\
& \quad \left. \left(R(t) \sin(\theta(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) \left(\frac{L_0}{2} + \eta_1(t) \right) \right)^2 \right)^{3/2} \Bigg) + \\
& (\mu M_{P1} \left(2 \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) \right. \\
& \quad \left(-R(t) \sin(\theta(t)) - \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) + \\
& \quad 2 \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) \\
& \quad \left. \left(R(t) \sin(\theta(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right) \right) \Bigg) / \\
& \left(2 \left(\sin^2(\alpha(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right)^2 + \right. \\
& \quad \left(\cos(\theta(t)) R(t) + \cos(\alpha(t)) \cos(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right)^2 + \\
& \quad \left. \left(R(t) \sin(\theta(t)) + \cos(\alpha(t)) \sin(\theta(t) + \psi(t)) (L_0 + \eta_1(t) + \eta_{P1}(t)) \right)^2 \right)^{3/2} \Bigg) = Q_\theta
\end{aligned}$$