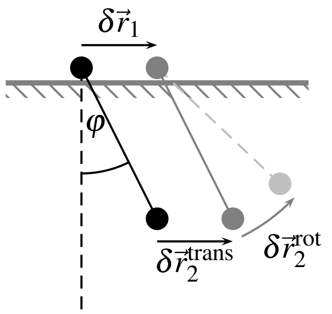
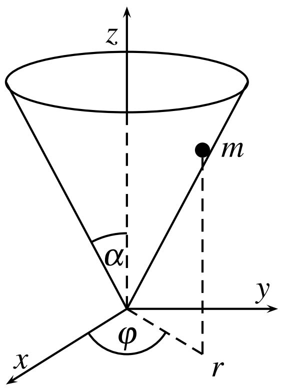


Auflagekraft $\vec Z_{\rm S}$, Fadenspannung $\vec Z_{\rm F}$

$$\vec Z_1\cdot\delta\vec r_1=(\vec Z_{\rm S}+\vec Z_{\rm F})\cdot\delta\vec r_1=\vec Z_{\rm F}\cdot\delta\vec r_1\neq 0$$

$$\begin{aligned}\vec Z_2\cdot\delta\vec r_2&=-\vec Z_{\rm F}(\delta\vec r_2^{\rm trans}+\delta\vec r_2^{\rm rot})\\&=-\vec Z_{\rm F}\cdot\delta\vec r_2^{\rm trans}=-\vec Z_{\rm F}\cdot\delta\vec r_1\neq 0\,.\end{aligned}$$

$$\begin{aligned}0&=(m\ddot{\vec r}-m\vec g)\cdot\delta\vec r\\&=m\big(\ddot x\delta x+\ddot y\delta y+(\ddot z+g)\delta z\big)\end{aligned}$$



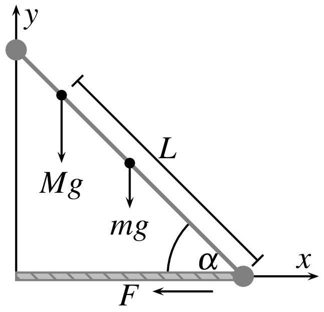
Zylinderkoord.: $(x,y,z)=r(\cos\varphi,\sin\varphi,\cot\alpha)$

$$\begin{aligned}\ddot x&=\ddot r\cos\varphi-2\dot r\dot\varphi\sin\varphi-r\ddot\varphi\sin\varphi-r\dot\varphi^2\cos\varphi\\\ddot y&=\ddot r\sin\varphi+2\dot r\dot\varphi\cos\varphi+r\ddot\varphi\cos\varphi-r\dot\varphi^2\sin\varphi\\\ddot z&=\ddot r\cot\alpha\end{aligned}$$

Virtuelle Verrückungen:

$$\begin{aligned}\delta x&=\delta r\,\cos\varphi-r\sin\varphi\,\delta\varphi\\\delta y&=\delta r\,\sin\varphi+r\cos\varphi\,\delta\varphi\\\delta z&=\delta r\,\cot\alpha\,.\end{aligned}$$

$$\underbrace{\big[2\dot r\dot\varphi+r\ddot\varphi\big]}_{=0}r\delta\varphi+\underbrace{\big[(\tan\alpha+\cot\alpha)\ddot r-r\dot\varphi^2\tan\alpha+g\big]}_{=0}\cot\alpha\,\delta r=0\,.$$



d'Alembert-Gleichung für Statik ($\ddot{\vec r}=\ddot{\vec R}=0$)

$$\begin{aligned}0&=m\vec g\cdot\delta\vec r+M\vec g\cdot\delta\vec R+\vec F\cdot\delta\vec r_a\\&=-mg\delta y-Mg\delta Y-F\delta x_a\,.\end{aligned}$$

$$\left[-mg\frac{\ell}{2}\cos\alpha-Mg\cos\alpha+F\ell\sin\alpha\right]\,\delta\alpha=0\,.$$

$$F=g\cot\alpha\left[\frac{m}{2}+M\frac{L}{l}\right]\,.$$