2) $\boxed{q=\phi}$ $\quad \frac{d}{dt}\left(\frac{\partial}{\partial\dot\phi}\left(\frac{1}{2}mr^2\dot\phi^2\right)\right) + \frac{\partial\, mgz}{\partial\phi} = \underbrace{\lambda\frac{\partial\varphi}{\partial\phi}}_{Q_\phi}$ / $\varphi(r,z)$

(*3) $\quad \frac{d}{dt}\left(\frac{2}{2}\underbrace{mr^2\dot\phi}_{\ell}\right) = 0$ $\qquad \ell = mr^2\dot\phi$ / cantidad conservada momento angular

$\frac{d}{dt}(\ell)=0$; Q_ϕ = fuerza generalizada $\vec F\cdot\frac{\partial\vec r}{\partial\phi}=0$

ecuación de movimiento de ϕ

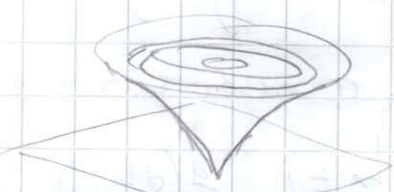
$$\ell = mr^2\dot\phi \rightarrow \dot\phi = \frac{\ell}{mr^2}$$

$$\frac{d}{dt}(mr^2\dot\phi) = 2mr\dot r\dot\phi + mr^2\ddot\phi = 0$$

ecu de movi

$\boxed{q=z}$ $\quad \frac{d}{dt}\left(\frac{\partial}{\partial\dot z}\left(\frac{1}{2}m\dot z^2\right)\right) + mg = \lambda\frac{\partial\varphi}{\partial z} = \lambda$

ec de mov de z / $m\ddot z = \lambda - mg$ $\quad$ (*4)



simplificando con (*3) $\quad \dot\phi = \frac{\ell}{mr^2}$; $\quad \varphi = z - \alpha\sin\left(\frac{r}{R}\right) = 0$

$$\boxed{\ddot z + \frac{\alpha}{R^2}\sin\left(\frac{r}{R}\right) = 0}$$

es. mov r) $\quad m\left(\ddot r + \dot r\frac{\ell^2}{m^2r^4} + 2\cancel{r}\frac{\ell}{mr^{\cancel{2}}}\ddot\phi\right) = -\frac{m\alpha}{R}\left(g - \frac{\alpha}{R^2}\sin\left(\frac{r}{R}\right)\right)\cos\left(\frac{r}{R}\right)$

/ $\frac{d}{dt}(mr^2\dot\phi)=0$; $\quad \ddot\phi = -\frac{2r\dot r\dot\phi}{mr^2} = -\frac{2\dot r\ell}{m^2r^3}$ $\quad : \frac{2\ell}{mr}\ddot\phi = -\frac{4\dot r\ell^2}{m^3r^4}$

$$m\left(\ddot r + \dot r\left(\frac{\ell}{mr^2}\right)^2 - \frac{4}{m}\left(\frac{\ell}{mr^2}\right)^2\right) = \boxed{m\left(\ddot r + \dot r\left(\frac{\ell}{mr^2}\right)^2\left[1-\frac{4}{m}\right]\right) = \frac{m\alpha}{R}\left(\frac{\alpha}{R^2}\sin\left(\frac{r}{R}\right) - g\right)\cos\left(\frac{r}{R}\right)}$$

ecuación de movimiento para r

(*5)