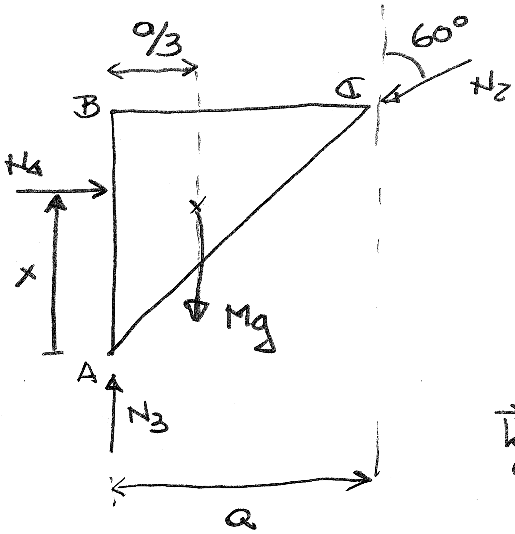
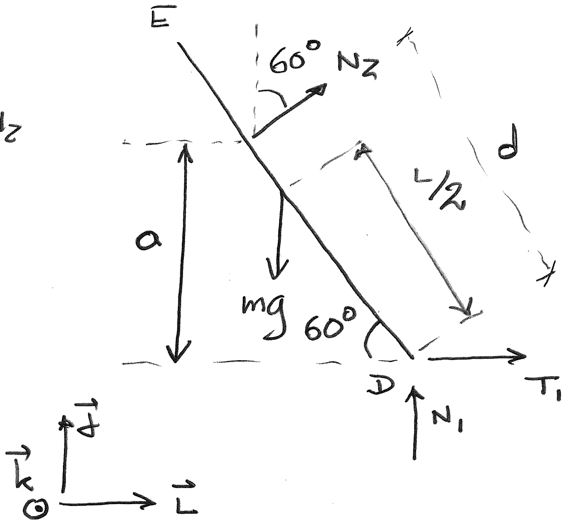
## Ejercicio N° 1

parte a:




parte b: 1ª según $\vec{i}$) $T_1 + N_2 \,\text{sen}\, 60° = 0$ ; $\text{sen}\,60° = \frac{\sqrt{3}}{2}$

1ª según $\vec{j}$) $N_1 - mg + N_2 \cos 60° = 0$ ; $\cos 60° = \frac{1}{2}$

2ª en D.: $mg \frac{L}{2} \cos 60° - N_2 d = 0$ ; $\cos 60° = 1/2$

$$\frac{a}{d} = \text{sen}\, 60° = \frac{\sqrt{3}}{2} \Rightarrow d = \frac{2a}{\sqrt{3}} \Rightarrow N_2 = \frac{mgL}{4d} = \frac{mgL\sqrt{3}}{8a} > 0$$

No hay desprendimiento en C.

$$N_1 = mg - \frac{mgL\sqrt{3}}{16a} \geq 0 \Rightarrow \boxed{L \leq \frac{16a}{\sqrt{3}}}$$

Primera condición. Si no se cumple la barra desprende en D.

$$T_1 = -\frac{mgL3}{16a} < 0$$

$$|T_1| \leq f|N_1| \Rightarrow \frac{mgL3}{16a} \leq f mg\left(1 - \frac{\sqrt{3}L}{16a}\right)$$

$$\boxed{f \geq \frac{3L}{16a - \sqrt{3}L}}$$

Segunda condición. Si no se cumple la barra desliza en D.

$L = \frac{4a}{\sqrt{3}}$ , $f = \frac{1}{\sqrt{2}}$

parte c: $\frac{4a}{\sqrt{3}} < \frac{16a}{\sqrt{3}}$ → No hay desprendimiento en D

$\frac{1}{\sqrt{2}} \; ? \; \frac{3L}{16a - 4a} = \frac{\sqrt{3}\,4}{12} = \frac{1}{\sqrt{3}}$

$\sqrt{3} \; ? \; \sqrt{2} \Rightarrow 3 > 2$ → Entonces se cumple la condición y no hay deslizamiento en D

$N_2 = \frac{mg\sqrt{3}}{8a} \cdot \frac{4a}{\sqrt{3}} = \frac{mg}{2}$

parte d: 1ª según $\vec{i}$) $N_4 - N_2 \operatorname{sen} 60° = 0$ (con $\operatorname{sen} 60° = \frac{\sqrt{3}}{2}$)

1ª " $\vec{j}$) $N_3 - Mg - N_2 \cos 60° = 0$ (con $\cos 60° = \frac{1}{2}$)

2 en C: $N_4 (a - x) + Mg\frac{2a}{3} - N_3 a = 0$

$N_4 = \frac{mg}{2}\frac{\sqrt{3}}{2} = \frac{\sqrt{3}\,mg}{4} > 0$ No hay desprendimiento de la pared.

$N_3 = Mg + \frac{mg}{4} > 0$ No hay desprendimiento del piso

$$x = a + \frac{Mg\frac{2a}{3} - \left(Mg + \frac{mg}{4}\right)a}{\frac{\sqrt{3}\,mg}{4}} = a - \frac{1}{\sqrt{3}}\left(\frac{4}{3}\frac{M}{m} + 1\right)a$$

$0 \leq x \leq a$ $\quad x < a \Rightarrow$ No hay vuelco en B.

$x \geq 0 \qquad a \geq \frac{1}{\sqrt{3}}\left(\frac{4}{3}\frac{M}{m} + 1\right)a$

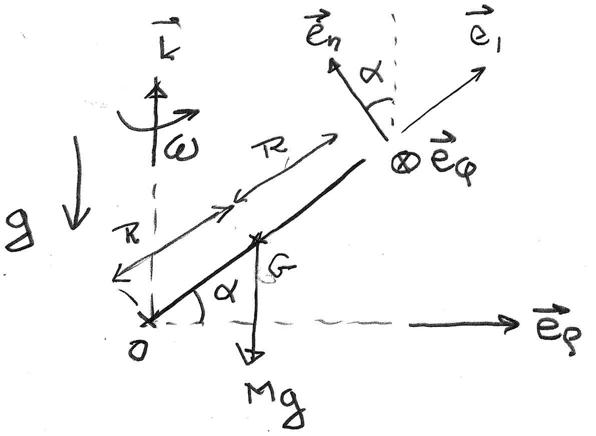
$3\sqrt{3} \geq 4\frac{M}{m} + 3$

$$\boxed{M \leq \frac{3(\sqrt{3} - 1)}{4} m}$$

Última condición.
Si no se cumple hay vuelco en A.

Ejercicio N° 2






$\alpha > 0$ constante

$\omega$ constante

parte a: O

$\vec{v}_G = \underset{0}{\vec{v}_O} + \vec{\omega} \wedge (G-O)$

$\boxed{\vec{\omega} = \omega \vec{k}}$

$G - O = R\vec{e}_1$

$\vec{v}_G = \omega R \vec{k} \wedge \vec{e}_1 = \boxed{\omega R \cos\alpha \, \vec{e}_\varphi = \vec{v}_G}$

$\vec{a}_G = \underset{0}{\vec{a}_O} + \underset{0}{\dot{\vec{\omega}}} \wedge (G-O) + \vec{\omega} \wedge [\vec{\omega} \wedge (G-O)] = \omega^2 R \cos\alpha \underbrace{\vec{k} \wedge \vec{e}_\varphi}_{-\vec{e}_\rho}$

$\boxed{\vec{a}_G = -\omega^2 R \cos\alpha \, \vec{e}_\rho}$

parte b: $\vec{L}_O = \mathbb{I}_O \vec{\omega}$ porque O es fijo.

$\vec{\omega} = \omega (\cos\alpha \, \vec{e}_n + \operatorname{sen}\alpha \, \vec{e}_1)$

$\vec{L}_O = \omega (\cos\alpha \, \mathbb{I}_O \vec{e}_n + \operatorname{sen}\alpha \, \mathbb{I}_O \vec{e}_1)$

$\vec{e}_n$ eje principal porque es perpendicular al plano del disco que es plano de simetría y O pertenece a ese plano.

$\vec{e}_1$ es eje principal porque es eje de simetría y O pertenece a ese eje.

$\Rightarrow \vec{L}_O = \omega (\cos\alpha \, I_{O,\vec{e}_n} \vec{e}_n + \operatorname{sen}\alpha \, I_{O,\vec{e}_1} \vec{e}_1)$

$I_{O,\vec{e}_n} = \frac{3MR^2}{2} = \underset{\frac{MR^2}{2}}{I_{G,\vec{e}_n}} + M \underset{R^2}{d^2_{O\vec{e}_n;G\vec{e}_n}}$ $\qquad I_{O,\vec{e}_1} = I_{G,\vec{e}_1} + M \underset{0}{d^2_{O\vec{e}_1;G\vec{e}_1}}$

Figura plana: $I_{G,\vec{e}_1} + I_{G,\vec{e}_\varphi} = I_{G,\vec{e}_n}$

Por simetría: $I_{G,\vec{e}_1} = I_{G,\vec{e}_\varphi} \Rightarrow 2 I_{G,\vec{e}_1} = I_{G,\vec{e}_n} = \frac{MR^2}{2} \Rightarrow I_{G,\vec{e}_1} = \frac{MR^2}{4}$

$$\boxed{\vec{L}_O = \frac{MR^2\omega}{4} (6\cos\alpha \, \vec{e}_n + \operatorname{sen}\alpha \, \vec{e}_1)}$$

Otra forma: $\vec{L}_O = \vec{L}_G + \vec{P} \wedge (O-G)$

$\vec{L}_G = \omega (\cos\alpha \, \mathbb{I}_G \vec{e}_n + \operatorname{sen}\alpha \, \mathbb{I}_G \vec{e}_1)$

$\vec{e}_n$ y $\vec{e}_1$ también son ejes principales en G por las mismas razones de antes, además $\vec{e}_n$ es eje de simetría en G y $\vec{e}_1$ es perpendicular a un plano de simetría y G pertenece a ellos

$$\vec{L}_G = \omega\left(\cos\alpha\, I_{G,\vec{e}_n}\vec{e}_n + \operatorname{sen}\alpha\, I_{G,\vec{e}_1}\vec{e}_1\right)$$

$M\vec{v}_G$ ; $I_{G,\vec{e}_n} = \frac{MR^2}{2}$ ; $I_{G,\vec{e}_1} = \frac{MR^2}{4}$

$$\vec{P}\wedge(O-G) = M\omega R\cos\alpha\,\vec{e}_\varphi \wedge (-R\vec{e}_1) = MR^2\omega\cos\alpha\,\vec{e}_n$$

$$\vec{L}_O = \frac{MR^2\omega}{4}\left(2\cos\alpha\,\vec{e}_n + \operatorname{sen}\alpha\,\vec{e}_1 + 4\cos\alpha\,\vec{e}_n\right) \checkmark$$

parte c: $M\vec{a}_G = \vec{R}^{(ext)} = \vec{R}^{(react)} - Mg\vec{k} \Rightarrow \vec{R}^{(react)} = M(g\vec{k} + \vec{a}_G)$

$$\boxed{\vec{R}^{(react)} = M\left(g\vec{k} - \omega^2 R\cos\alpha\,\vec{e}_\varphi\right)}$$

parte d: $\dot{\vec{L}}_O = \vec{M}_O^{(ext)} = \vec{M}_O^{(react)} + \vec{M}_O^{g}$ (O fijo)

$\vec{M}_O^{g} = (G-O)\wedge(-Mg\vec{k}) = -MgR\,\vec{e}_1\wedge\vec{k} = MgR\cos\alpha\,\vec{e}_\varphi$ ; $\vec{e}_1\wedge\vec{k} = -\cos\alpha\,\vec{e}_\varphi$

$$\dot{\vec{L}}_O = \frac{MR^2\omega}{4}\left(6\cos\alpha\,\dot{\vec{e}}_n + \operatorname{sen}\alpha\,\dot{\vec{e}}_1\right)$$

$$\dot{\vec{e}}_n = \vec{\omega}\wedge\vec{e}_n = \omega\vec{k}\wedge\vec{e}_n = -\omega\operatorname{sen}\alpha\,\vec{e}_\varphi$$

$$\dot{\vec{e}}_1 = \vec{\omega}\wedge\vec{e}_1 = \omega\vec{k}\wedge\vec{e}_1 = \omega\cos\alpha\,\vec{e}_\varphi$$

$$\dot{\vec{L}}_O = \frac{MR^2\omega^2}{4}\left(-6\cos\alpha\operatorname{sen}\alpha + \operatorname{sen}\alpha\cos\alpha\right)\vec{e}_\varphi = -\frac{5MR^2\omega^2\operatorname{sen}\alpha\cos\alpha}{4}\vec{e}_\varphi$$

$$\boxed{\vec{M}_O^{(react)} = -\frac{5MR^2\omega^2}{4}\operatorname{sen}\alpha\cos\alpha\,\vec{e}_\varphi - MgR\cos\alpha\,\vec{e}_\varphi}$$

parte e: $|\vec{M}_O^{(react)}| \leq M_O^{max}$

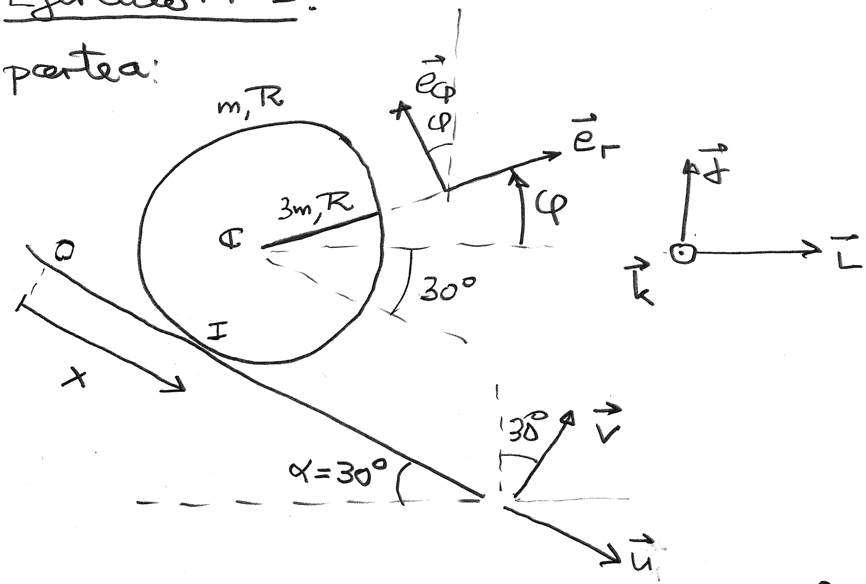
$$0<\alpha<\frac{\pi}{2} \Rightarrow \frac{5MR^2\omega^2\operatorname{sen}\alpha\cos\alpha}{4} + MgR\cos\alpha \leq M_O^{max}$$

$$\boxed{\omega \leq \sqrt{\frac{4\left(M_O^{max} - MgR\cos\alpha\right)}{5MR^2\operatorname{sen}\alpha\cos\alpha}}}$$

Si $M_O^{max} < MgR\cos\alpha$ el radicando es negativo $\Rightarrow \nexists\, \omega_{max}$
Lo que sucede en este caso es que ya el momento del peso es mayor que el $M_O^{max}$ $\Rightarrow$ la soldadura no alcanza a aguantar el momento del peso ni cuando el disco está quieto.

## Ejercicio Nº 3:

parte a:




$$\vec v_I = \vec v_C + \vec\omega \wedge (I - C) = 0 \Rightarrow \dot x \vec u + R\dot\varphi \vec u = 0 \Rightarrow \boxed{\dot x + R\dot\varphi = 0}$$

$\vec v_C = \dot x \vec u$, $\quad \vec\omega = \dot\varphi \vec k$, $\quad (I - C) = -R\vec v$

La distancia C - I es constante e igual a R

parte b: $\vec r_G = \dfrac{1}{4m}\left(m\vec r_C + 3m\vec r_G^{(barra)}\right) = \vec r_C + \dfrac{3}{8}R\vec e_r$

$$\vec r_G^{(barra)} = \vec r_C + \frac{R}{2}\vec e_r$$

$$\vec r_C = \vec r_O + x\vec u + R\vec v$$

$$\vec e_r = \cos(\varphi + 30°)\vec u + \operatorname{sen}(\varphi + 30°)\vec v$$

$$\Rightarrow \boxed{\vec r_G = \vec r_O + x\vec u + R\vec v + \frac{3R}{8}\left[\cos(\varphi+30°)\vec u + \operatorname{sen}(\varphi+30°)\vec v\right]}$$

parte c: 1) Internas $\Rightarrow$ Potencia Nula

2) Peso $\Rightarrow$ Conservativo $\Rightarrow U = 4mg\,y_G$, $\quad y_G = \vec r_G \cdot \vec J$

$$\vec r_G \cdot \vec J = \vec r_C \cdot \vec J + \frac{3}{8}R\,\underbrace{\vec e_r \cdot \vec J}_{\operatorname{sen}\varphi}$$

$$\vec r_C \cdot \vec J = x\,\underbrace{\vec u \cdot \vec J}_{-\operatorname{sen}30° = -\frac{1}{2}} + R\,\underbrace{\vec v \cdot \vec J}_{\cos 30° = \frac{\sqrt{3}}{2}}$$

$\Rightarrow$ A menos de una constante $\quad U = -2mgx + \dfrac{3mgR}{2}\operatorname{sen}\varphi$

$$x = -R\varphi \Rightarrow \boxed{U = mgR\left(2\varphi + \frac{3}{2}\operatorname{sen}\varphi\right)}$$

3) Reacción en I: $P = \vec R^{(reac)} \cdot \vec v_I + \vec\omega \cdot \vec M_I^{(reac)} = 0$, $\quad \vec v_I = 0$, $\quad \vec M_I^{(reac)} = 0$

$\Rightarrow$ de Potencia Nula $\qquad$ porque fuerza aplicada en I parte d: Sist. Conservativo $\Rightarrow T+U=E=cte.$

$$T=\frac{M\vec{v}_P^{\,2}}{2}+M\vec{v}_P\cdot\left[\vec{\omega}\wedge(G-P)\right]+\frac{1}{2}\vec{\omega}\cdot\mathbb{I}_P\vec{\omega}$$

Aplicamos en $P=\mathbb{C}$: $T=\frac{M\vec{v}_C^{\,2}}{2}+M\vec{v}_C\cdot\left[\vec{\omega}\wedge(G-\mathbb{C})\right]+\frac{1}{2}\vec{\omega}\cdot\mathbb{I}_C\vec{\omega}$

$$\vec{v}_C=\dot{x}\vec{u}\Rightarrow\frac{M\vec{v}_C^{\,2}}{2}=\frac{M\dot{x}^2}{2}=\frac{MR^2\dot{\varphi}^2}{2}=\frac{4mR^2\dot{\varphi}^2}{2}=2mR^2\dot{\varphi}^2$$

$$M\vec{v}_C\cdot\left[\vec{\omega}\wedge(G-\mathbb{C})\right]=M\dot{x}\dot{\varphi}\frac{3R}{8}\left[\vec{u}\cdot\underbrace{(\vec{k}\wedge\vec{e}_r)}_{\vec{e}_\varphi}\right]$$

$$\vec{u}\cdot\vec{e}_\varphi=\cos(\varphi+30°+90°)=-\operatorname{sen}(\varphi+30°)=-\cos(60°-\varphi)$$

($30° = 90°-60°$)

$$M\vec{v}_C\cdot\left[\vec{\omega}\wedge(G-\mathbb{C})\right]=-M\dot{x}\dot{\varphi}\frac{3R}{8}\cos(60°-\varphi)=\frac{3mR^2\dot{\varphi}^2}{2}\cos(60°-\varphi)$$

$$\frac{1}{2}\vec{\omega}\cdot\mathbb{I}_C\vec{\omega}=\frac{\dot{\varphi}^2}{2}\vec{k}\cdot\mathbb{I}_C\vec{k}$$

$$I_{C\vec{k}}=I^{disco}_{\mathbb{C},\vec{k}}+I^{barra}_{C,\vec{k}}=\frac{3mR^2}{2}$$

$$I^{disco}_{\mathbb{C},\vec{k}}=\frac{mR^2}{2}$$

$$I^{barra}_{C,\vec{k}}=I^{barra}_{G^{barra},\vec{k}}+3m\,d^2_{\mathbb{C},\vec{k};G^{barra},\vec{k}}=$$

$$I^{barra}_{G^{barra},\vec{k}}=\frac{3mR^2}{12},\qquad d^2=\frac{R^2}{4}$$

$$=\frac{3mR^2}{12}(3+1)=mR^2$$

$$T=2mR^2\dot{\varphi}^2+\frac{3mR^2\dot{\varphi}^2}{2}\cos(60°-\varphi)+\frac{3mR^2\dot{\varphi}^2}{4}$$

$$T=\frac{mR^2\dot{\varphi}^2}{4}\left[11+6\cos(60°-\varphi)\right]$$

Otra forma: $P=I$ / $\vec{v}_I=0\Rightarrow T=\frac{1}{2}\vec{\omega}\cdot\mathbb{I}_I\vec{\omega}=\frac{\dot{\varphi}^2}{2}\vec{k}\cdot\mathbb{I}_I\vec{k}$

$$\vec{k}\cdot\mathbb{I}_I\vec{k}=I_{I,\vec{k}}=I_{G\vec{k}}+4m\,d^2_{I,\vec{k};G,\vec{k}}$$

$$I_{G\vec{k}}=I^{(disco)}_{G,\vec{k}}+I^{(barra)}_{G,\vec{k}}$$

$$I^{(disco)}_{G,\vec{k}}=I^{(disco)}_{C,\vec{k}}+m\,d^2_{G,\vec{k};\mathbb{C},\vec{k}}=\frac{mR^2}{2}+m\frac{9R^2}{64}$$

$$I^{(barra)}_{G,\vec{k}}=I^{(barra)}_{G^{barra},\vec{k}}+3m\,d^2_{G^{barra},\vec{k}}=\frac{3mR^2}{12}+3m\left(\frac{3R}{8}-\frac{R}{2}\right)^2,\qquad \left(\frac{3R}{8}-\frac{R}{2}\right)^2=\frac{R^2}{64}$$

$$\frac{3mR^2}{12}=\frac{mR^2}{4}$$

$$I_{G\vec{k}}=\frac{3mR^2}{4}+\frac{12mR^2}{64}=\frac{mR^2}{16}(12+3)=\frac{15mR^2}{16}$$

Mecánica Newtoniana (1122) Segundo Parcial (11/7/2024) (7/8)

$$d^2_{I\vec{k},G\vec{k}} = (G-I)^2 = (\underbrace{G-C}_{\frac{3R}{8}\vec{e}_r} + \underbrace{C-I}_{R\vec{v}})^2 = \frac{9R^2}{64} + R^2 + \frac{3R^2}{4}\underbrace{\vec{e}_r\cdot\vec{v}}_{\cos(60^\circ-\varphi)}$$

$$I_{I\vec{k}} = \frac{15mR^2}{16} + \frac{9mR^2}{16} + 4mR^2 + 3mR^2\cos(60^\circ-\varphi) =$$

$$= mR^2\left(\underbrace{\frac{24}{16}}_{\frac{3}{2}} + 4 + 3\cos(60^\circ-\varphi)\right) = \frac{mR^2}{2}\left(11+6\cos(60^\circ-\varphi)\right)$$

$$\Rightarrow T = \frac{mR^2}{4}\left[11+6\cos(60^\circ-\varphi)\right]\dot{\varphi}^2 \quad ✓$$

Otra forma: $T = \dfrac{M\vec{v}_G^2}{2} + \dfrac{1}{2}\vec{\omega}\cdot\mathbb{I}_G\vec{\omega}$

$$\vec{v}_G = \vec{v}_C + \frac{3}{8}R\dot{\varphi}\vec{e}_\varphi = \dot{x}\vec{u} + \frac{3}{8}R\dot{\varphi}\vec{e}_\varphi$$

$$\frac{M\vec{v}_G^2}{2} = \frac{4m}{2}\left[\dot{x}^2 + \frac{9}{64}R^2\dot{\varphi}^2 + \frac{3\dot{x}R\dot{\varphi}}{4}\underbrace{\vec{u}\cdot\vec{e}_\varphi}_{-\cos(60^\circ-\varphi)}\right] =$$

$$= 2m\left[\frac{73}{64}R^2\dot{\varphi}^2 + \frac{3R^2\dot{\varphi}^2}{4}\cos(60^\circ-\varphi)\right] =$$

$$= mR^2\dot{\varphi}^2\left[\frac{73}{32} + \frac{3}{2}\cos(60^\circ-\varphi)\right]$$

$$\frac{1}{2}\vec{\omega}\cdot\mathbb{I}_G\vec{\omega} = \frac{\dot{\varphi}^2}{2}\vec{k}\cdot\mathbb{I}_G\vec{k} = \frac{\dot{\varphi}^2}{2}I_{G\vec{k}} = \frac{15mR^2\dot{\varphi}^2}{32}$$

$$T = mR^2\dot{\varphi}^2\left[\underbrace{\frac{88}{32}}_{\frac{11}{4}} + \frac{3}{2}\cos(60^\circ-\varphi)\right] = \frac{mR^2\dot{\varphi}^2}{4}\left[11+6\cos(60^\circ-\varphi)\right]$$

$$\Rightarrow \frac{mR^2\dot{\varphi}^2}{4}\left[11+6\cos(60^\circ-\varphi)\right] + mgR\left(2\varphi + \frac{3}{2}\operatorname{sen}\varphi\right) = E = cte$$

$$\frac{mR^2\dot{\varphi}\ddot{\varphi}}{2}\left[11+6\cos(60^\circ-\varphi)\right] + \frac{mR^2\dot{\varphi}^3}{4}6\operatorname{sen}(60^\circ-\varphi) + mgR\left(2\dot{\varphi} + \frac{3}{2}\cos\varphi\,\dot{\varphi}\right) = 0$$

$$\boxed{R\ddot{\varphi}\left[11+6\cos(60^\circ-\varphi)\right] + 3\operatorname{sen}(60^\circ-\varphi)R\dot{\varphi}^2 + g\left(4+3\cos\varphi\right) = 0}$$

Por cardinales: $\dot{\vec{L}}_I = M\vec{v}_G \wedge \dot{I} + \vec{M}_I^{(ext)}$

$$\vec{L}_I = M\underbrace{(G-I)\wedge\vec{v}_I}_{0} + \mathbb{I}_I\vec{\omega} = \dot{\varphi}\,\mathbb{I}_I\vec{k} = \dot{\varphi}\, I_{I\vec{k}}\,\vec{k}$$

$$\vec{L}_I = \frac{mR^2\dot{\varphi}}{2}\left[11+6\cos(60^\circ-\varphi)\right]\vec{k}$$

$$\dot{\vec{L}}_I = \frac{mR^2\ddot{\varphi}}{2}\left[11+6\cos(60^\circ-\varphi)\right] + mR^2\dot{\varphi}^2\, 3\,\mathrm{sen}(60^\circ-\varphi)$$

$$I = C - R\vec{v} \Rightarrow \dot{I} = \dot{C} = \dot{x}\vec{u}$$

$$M\vec{v}_G\wedge\dot{I} = 4m\left(\dot{x}\vec{u} + \frac{3}{8}R\dot{\varphi}\vec{e}_\varphi\right)\wedge\dot{x}\vec{u} = \frac{3mR\dot{\varphi}}{2}\underbrace{\vec{e}_\varphi\wedge\vec{u}}_{-\mathrm{sen}(120^\circ+\varphi)(-\vec{k})}\dot{x}$$

$$M\vec{v}_G\wedge\dot{I} = \frac{3mR^2\dot{\varphi}^2}{2}\mathrm{sen}(60^\circ-\varphi)\vec{k}$$

$\mathrm{sen}(60^\circ-\varphi) = \cos(90^\circ-60^\circ+\varphi) = \cos(\varphi+30^\circ)$

$$\vec{M}_I^{(ext)} = (G-I)\wedge(-4mg\vec{j}) = \left(\frac{3R}{8}\vec{e}_r + R\vec{v}\right)(-4mg\vec{j}) =$$

$$= -4mgR\left(\frac{3}{8}\underbrace{\vec{e}_r\wedge\vec{j}}_{\cos\varphi\,\vec{k}} + \underbrace{\vec{v}\wedge\vec{j}}_{\mathrm{sen}30^\circ\,\vec{k} = \frac{\vec{k}}{2}}\right) = -mgR\left(2+\frac{3}{2}\cos\varphi\right)\vec{k}$$

$$\frac{mR^2\ddot{\varphi}}{2}\left[11+6\cos(60^\circ-\varphi)\right] + 3mR^2\dot{\varphi}^2\,\mathrm{sen}(60^\circ-\varphi) =$$

$$= \frac{3mR^2\dot{\varphi}^2}{2}\mathrm{sen}(60^\circ-\varphi) - mgR\left(2+\frac{3}{2}\cos\varphi\right)$$

$$R\ddot{\varphi}\left[11+6\cos(60^\circ-\varphi)\right] + 3R\dot{\varphi}^2\,\mathrm{sen}(60^\circ-\varphi) + g(4+3\cos\varphi) = 0 \checkmark$$