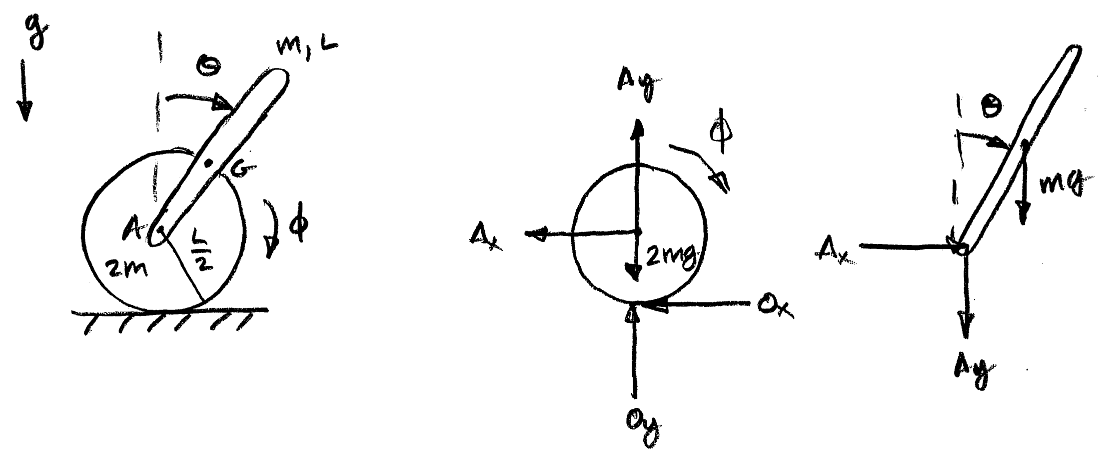
1)



DISK:

$$\left[M_O = I_O \ddot{\phi}\right]$$

$$-A_x \frac{L}{2} = \Big[\underbrace{\tfrac{1}{2}(2m)\left(\tfrac{L}{2}\right)^2}_{I_A} + \underbrace{(2m)\left(\tfrac{L}{2}\right)^2}_{md^2}\Big]\ddot{\phi}$$

$$-\frac{A_x L}{2} = \left(\frac{mL^2}{4} + \frac{2mL^2}{4}\right)\ddot{\phi} \Rightarrow -\frac{A_x L}{2} = \frac{3mL^2}{4}\ddot{\phi}$$

$$\Rightarrow \ddot{\phi} = -\frac{2A_x}{3mL} \quad (1)$$

Rod:

$$\left[M_G = I_G \ddot{\theta}\right]$$

$$-\frac{A_x \cancel{L}}{\cancel{2}}\cos\theta - \frac{A_y \cancel{L}}{\cancel{2}}\sin\theta = \frac{mL^{\cancel{2}}}{6\,\cancel{12}}\ddot{\theta}$$

$$\frac{mL}{6}\ddot{\theta} = -A_x\cos\theta - A_y\sin\theta \quad (2)$$

Need two more equations. Use Newton's 2nd law on rod:

$$\vec{r}_G = \left(x + \tfrac{L}{2}\sin\theta\right)\hat{\imath} + \tfrac{L}{2}\cos\theta\,\hat{\jmath}$$

$$\dot{\vec{r}}_G = \left(\dot{x} + \tfrac{L}{2}\dot{\theta}\cos\theta\right)\hat{\imath} - \tfrac{L}{2}\dot{\theta}\sin\theta\,\hat{\jmath}$$

$$\ddot{\vec{r}}_G = \left(\ddot{x} + \tfrac{L}{2}\ddot{\theta}\cos\theta - \tfrac{L}{2}\dot{\theta}^2\sin\theta\right)\hat{\imath} - \tfrac{L}{2}\ddot{\theta}\sin\theta\,\hat{\jmath} - \tfrac{L}{2}\dot{\theta}^2\cos\theta\,\hat{\jmath}$$

But $x = \frac{L}{2}\phi \Rightarrow \ddot{x} = \frac{L}{2}\ddot{\phi}$

and $\dot{\theta} = \dot{\phi} = 0$

$$\ddot{\vec{r}}_G = \left(\frac{L}{2}\ddot{\phi} + \frac{L}{2}\ddot{\theta}\cos\theta\right)\hat{\imath} - \frac{L}{2}\ddot{\theta}\sin\theta\,\hat{\jmath}$$

$$\left[\vec{F} = m\ddot{\vec{r}}_G\right]$$

$$\hat{\imath}:\ A_x = \frac{mL}{2}\ddot{\phi} + \frac{mL}{2}\ddot{\theta}\cos\theta \quad (3)$$

$$\hat{\jmath}:\ -A_y - mg = -\frac{mL}{2}\ddot{\theta}\sin\theta \quad (4)$$

From (2):

$$\ddot{\theta} = -\frac{6A_x}{mL}\cos\theta - \frac{6A_y}{mL}\sin\theta \quad (5)$$

Substitute into (3):

$$A_x = \frac{mL}{2}\ddot{\phi} + \frac{\cancel{mL}}{2}\left(-\frac{6A_x}{\cancel{mL}}\cos\theta - \frac{6A_y}{\cancel{mL}}\sin\theta\right)\cos\theta$$

$$A_x = \frac{mL}{2}\ddot{\phi} - 3A_x\cos^2\theta - 3A_y\sin\theta\cos\theta$$

$$A_x(1+3\cos^2\theta) + 3A_y\sin\theta\cos\theta = \frac{mL}{2}\ddot{\phi} \quad (6)$$

Substitute (5) into (4):

$$-A_y - mg = +\frac{\cancel{mL}}{2}\left(+\frac{6A_x}{\cancel{mL}}\cos\theta + \frac{6A_y}{\cancel{mL}}\sin\theta\right)\sin\theta$$

$$-A_y - mg = 3A_x\sin\theta\cos\theta + 3A_y\sin^2\theta$$

$$3A_x\sin\theta\cos\theta + A_y(1+3\sin^2\theta) = -mg$$

$$A_y = \frac{-mg - 3A_x\sin\theta\cos\theta}{1+3\sin^2\theta}$$

Substitute into (6):

$$A_x(1+3\cos^2\theta)+3\left(\frac{-mg-3A_x\sin\theta\cos\theta}{1+3\sin^2\theta}\right)\sin\theta\cos\theta=\frac{mL}{2}\ddot{\phi}$$

$$A_x(1+3\cos^2\theta)-\frac{3mg\sin\theta\cos\theta}{1+3\sin^2\theta}-\frac{9A_x\sin^2\theta\cos^2\theta}{1+3\sin^2\theta}=\frac{mL}{2}\ddot{\phi}$$

Use numerical values: $\theta = 30°$

$$3.25A_x - 0.742mg - 0.9643A_x = \frac{mL}{2}\ddot{\phi}$$

$$2.2857A_x = 0.742mg + \frac{mL}{2}\ddot{\phi}$$

$$A_x = 0.3248mg + 0.21875mL\ddot{\phi}$$

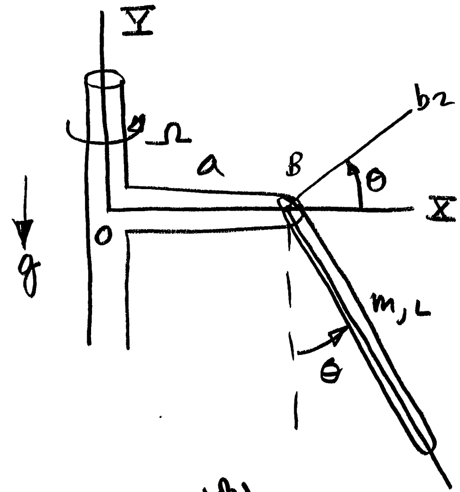
Substitute into ①:

$$\ddot{\phi} = -\frac{2}{3\cancel{mL}}\left[0.3248\cancel{m}\frac{g}{L} + 0.21875\cancel{mL}\ddot{\phi}\right]$$

$$\ddot{\phi}\left[1+0.14583\right] = -0.2165\frac{g}{L}$$

$$\boxed{\ddot{\phi} = -0.189\frac{g}{L}}$$

2) Problem 11.13 from Baruh.



The angular velocity of the pendulum is:

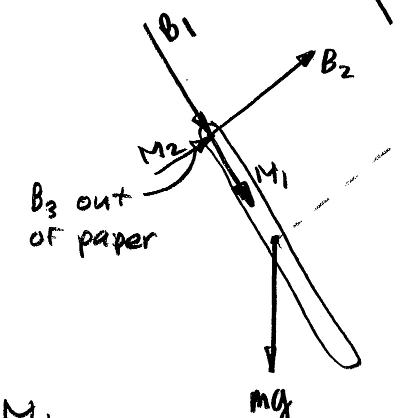
$$\vec{\omega} = -\Omega\cos\theta\,\hat{b}_1 + \Omega\sin\theta\,\hat{b}_2 + \dot{\theta}\,\hat{b}_3$$

Its inertia matrix is:

$$[I_G] = \frac{1}{12}mL^2\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The moments about G are:

$$\vec{M}_G = M_1\hat{b}_1 + \left(M_2 + \frac{B_3L}{2}\right)\hat{b}_2 - \frac{B_2L}{2}\hat{b}_3$$



$$\dot{\vec{\omega}} = \Omega\dot{\theta}\sin\theta\,\hat{b}_1 + \Omega\dot{\theta}\cos\theta\,\hat{b}_2 + \ddot{\theta}\,\hat{b}_3$$

Euler's equations:

$$I_1\dot{\omega}_1 - (I_2 - I_3)\omega_2\omega_3 = M_1$$

$$(0)\Omega\dot{\theta}\sin\theta - \left(\tfrac{1}{12}mL^2 - \tfrac{1}{12}mL^2\right)(\Omega\sin\theta)(\dot{\theta}) = M_1$$

$$\Rightarrow M_1 = 0$$

$$I_2\dot{\omega}_2 - (I_3 - I_1)\omega_1\omega_3 = M_2$$

$$\tfrac{1}{12}mL^2\Omega\dot{\theta}\cos\theta - \tfrac{1}{12}mL^2(-\Omega\cos\theta)(\dot{\theta}) = M_2 + \frac{B_3L}{2}$$

$$\tfrac{1}{6}mL^2\Omega\dot{\theta}\cos\theta = M_2 + \frac{B_3L}{2} \quad (1)$$

$$I_3\dot{\omega}_3 - (I_1 - I_2)\omega_1\omega_2 = M_3$$

$$\tfrac{1}{12}mL^2\ddot{\theta} - \left(0 - \tfrac{1}{12}mL^2\right)(-\Omega\cos\theta)(\Omega\sin\theta) = -\frac{B_2L}{2}$$

$$\tfrac{1}{12}mL^2\ddot{\theta} - \tfrac{1}{12}mL^2\Omega^2\sin\theta\cos\theta = -\frac{B_2L}{2} \quad (2)$$

We now have four unknown reactions (M_2, B_1, B_2, B_3), plus we need an equation of motion.

We only have two equations ((1) and (2)), and we need five.

$\Rightarrow$ Use Newton's 2nd Law

$$\vec{r}_G = a\hat{I} + \frac{L}{2}\hat{b}_1 = a(\sin\theta\,\hat{b}_1 + \cos\theta\,\hat{b}_2) + \frac{L}{2}\hat{b}_1$$

$$\vec{r}_G = \left(a\sin\theta + \frac{L}{2}\right)\hat{b}_1 + a\cos\theta\,\hat{b}_2$$

$$\dot{\vec{r}}_G = a\dot{\theta}\cos\theta\,\hat{b}_1 + \left(a\sin\theta + \frac{L}{2}\right)\dot{\hat{b}}_1 - a\dot{\theta}\sin\theta\,\hat{b}_2 + a\cos\theta\,\dot{\hat{b}}_2$$

$$\dot{\hat{b}}_1 = \vec{\omega}\times\hat{b}_1 = \Omega\sin\theta\,\hat{b}_2\times\hat{b}_1 + \dot{\theta}\,\hat{b}_3\times\hat{b}_1 = \dot{\theta}\,\hat{b}_2 - \Omega\sin\theta\,\hat{b}_3$$

$$\dot{\hat{b}}_2 = \vec{\omega}\times\hat{b}_2 = -\Omega\cos\theta\,\hat{b}_1\times\hat{b}_2 + \dot{\theta}\,\hat{b}_3\times\hat{b}_2 = -\dot{\theta}\,\hat{b}_1 - \Omega\cos\theta\,\hat{b}_3$$

$$\dot{\hat{b}}_3 = \vec{\omega}\times\hat{b}_3 = -\Omega\cos\theta\,\hat{b}_1\times\hat{b}_3 + \Omega\sin\theta\,\hat{b}_2\times\hat{b}_3$$
$$= \Omega\sin\theta\,\hat{b}_1 + \Omega\cos\theta\,\hat{b}_2$$

$$\dot{\vec{r}}_G = a\dot{\theta}\cos\theta\,\hat{b}_1 + \left(a\sin\theta + \frac{L}{2}\right)(\dot{\theta}\,\hat{b}_2 - \Omega\sin\theta\,\hat{b}_3) - a\dot{\theta}\sin\theta\,\hat{b}_2$$
$$+ a\cos\theta\,(-\dot{\theta}\,\hat{b}_1 - \Omega\cos\theta\,\hat{b}_3)$$

$$\dot{\vec{r}}_G = (a\dot{\theta}\cos\theta - a\dot{\theta}\cos\theta)\,\hat{b}_1 + \left(a\dot{\theta}\sin\theta + \frac{L}{2}\dot{\theta} - a\dot{\theta}\sin\theta\right)\hat{b}_2$$
$$+ \left(-a\Omega\sin^2\theta - \frac{L}{2}\Omega\sin\theta - a\Omega\cos^2\theta\right)\hat{b}_3$$

$$= \frac{L}{2}\dot{\theta}\,\hat{b}_2 - \left(\frac{L}{2}\Omega\sin\theta + a\Omega\right)\hat{b}_3$$

$$\dot{\vec{r}}_G = \frac{L}{2}\dot{\theta}\,\hat{b}_2 - \Omega\left(\frac{L}{2}\sin\theta + a\right)\hat{b}_3$$

$$\ddot{\vec{r}}_G = \frac{L}{2}\ddot{\theta}\,\hat{b}_2 + \frac{L}{2}\dot{\theta}\,(-\dot{\theta}\,\hat{b}_1 - \Omega\cos\theta\,\hat{b}_3) - \Omega\left(\frac{L}{2}\dot{\theta}\cos\theta\right)\hat{b}_3$$
$$- \Omega\left(\frac{L}{2}\sin\theta + a\right)(\Omega\sin\theta\,\hat{b}_1 + \Omega\cos\theta\,\hat{b}_2)$$

$$= \left[-\frac{L}{2}\dot{\theta}^2 - \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\sin\theta\right]\hat{b}_1 + \left[\frac{L}{2}\ddot{\theta} - \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\cos\theta\right]\hat{b}_2$$
$$+ \underbrace{\left[-\frac{L}{2}\dot{\theta}\Omega\cos\theta - \frac{L}{2}\dot{\theta}\Omega\cos\theta\right]\hat{b}_3}_{-L\dot{\theta}\Omega\cos\theta\,\hat{b}_3}$$

$$[\vec{F} = m\ddot{\vec{r}}_G]$$

$$\hat{b}_1:\quad B_1 + mg\cos\theta = m\left[-\frac{L}{2}\dot{\theta}^2 - \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\sin\theta\right]$$

$$\hat{b}_2:\quad B_2 - mg\sin\theta = m\left[\frac{L}{2}\ddot{\theta} - \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\cos\theta\right]$$

$\hat{b}_3$: $\boxed{B_3 = -mL\dot{\theta}\Omega\cos\theta}$

$$\boxed{B_1 = -m\left[g\cos\theta + \frac{L}{2}\dot{\theta}^2 + \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\sin\theta\right]}$$

$$\boxed{B_2 = m\left[g\sin\theta + \frac{L}{2}\ddot{\theta} - \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\cos\theta\right]}$$

From ②:

$$\frac{1}{12}\cancel{m}L^{\cancel{2}}\ddot{\theta} - \frac{1}{12}\cancel{m}L^{\cancel{2}}\Omega^2\sin\theta\cos\theta = -\frac{\cancel{L}}{2}\cancel{m}\left[g\sin\theta + \frac{L}{2}\ddot{\theta} - \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\cos\theta\right]$$

$$\frac{L}{6}\ddot{\theta} - \frac{L}{6}\Omega^2\sin\theta\cos\theta = -g\sin\theta - \frac{L}{2}\ddot{\theta} + \Omega^2\left(\frac{L}{2}\sin\theta + a\right)\cos\theta$$

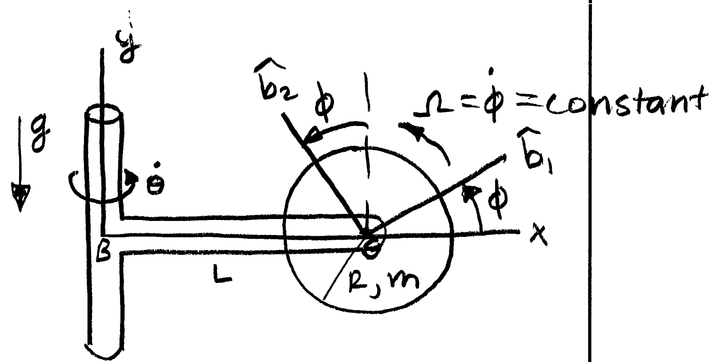
$$\frac{2L}{3}\ddot{\theta} + g\sin\theta - \frac{L}{6}\Omega^2\sin\theta\cos\theta - \frac{L}{2}\Omega^2\sin\theta\cos\theta - a\Omega^2\cos\theta = 0$$

$$\boxed{\frac{2L}{3}\ddot{\theta} + g\sin\theta - \frac{2L}{3}\Omega^2\sin\theta\cos\theta - a\Omega^2\cos\theta = 0} \quad \text{EOM}$$

or

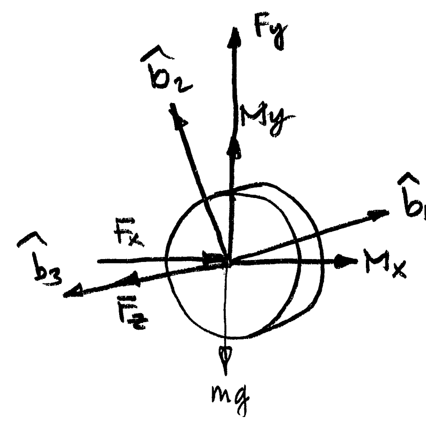
$$\frac{L}{3}\ddot{\theta} - \Omega^2\left(\frac{L}{3}\sin\theta + \frac{a}{2}\right)\cos\theta + \frac{g}{2}\sin\theta = 0$$

3)



$$\vec\omega = \dot\theta \hat{\jmath} + \Omega \hat b_3$$
$$\vec\omega = \dot\theta \sin\phi \hat b_1 + \dot\theta \cos\phi \hat b_2 + \Omega \hat b_3$$
$$\dot{\vec\omega} = [\ddot\theta \sin\phi + \dot\theta \Omega \cos\phi]\hat b_1 + [\ddot\theta\cos\phi - \dot\theta\Omega\sin\phi]\hat b_2$$

$$I_1 = \tfrac{1}{4} mR^2 \quad I_2 = \tfrac{1}{4} mR^2 \quad I_3 = \tfrac{1}{2} mR^2$$



$$M_1 = M_x \cos\phi + M_y \sin\phi$$
$$M_2 = M_y\cos\phi - M_x \sin\phi$$
$$M_3 = 0$$

Euler's equations:

$$\tfrac{1}{4} mR^2 (\ddot\theta \sin\phi + \dot\theta\Omega\cos\phi) + \tfrac{1}{4} mR^2 (\dot\theta\cos\phi)(\Omega) = M_x\cos\phi + M_y \sin\phi$$
$$\tfrac{1}{4} mR^2 \ddot\theta \sin\phi + \frac{mR^2}{2}\dot\theta\Omega\cos\phi = M_x\cos\phi + M_y\sin\phi \quad (1)$$

$$\tfrac{1}{4} mR^2 (\ddot\theta\cos\phi - \dot\theta\Omega\sin\phi) - \tfrac{1}{4} mR^2 (\dot\theta \sin\phi)(\Omega) = M_y\cos\phi - M_x\sin\phi$$
$$\frac{mR^2}{4}\ddot\theta\cos\phi - \frac{mR^2}{2}\dot\theta\Omega\sin\phi = M_y\cos\phi - M_x\sin\phi \quad (2)$$

$$\Rightarrow M_x = -\frac{mR^2}{4}\ddot\theta \frac{\cos\phi}{\sin\phi} + \frac{mR^2}{2}\dot\theta\Omega + M_y \frac{\cos\phi}{\sin\phi}$$

Plug into (1): $\Rightarrow M_y = \dfrac{mR^2}{4}\ddot\theta$

$$\Rightarrow M_x = \frac{mR^2}{2}\dot\theta\Omega$$

To find forces, use Newton's 2nd Law:

$$\vec r_G = L\hat\imath \Rightarrow \ddot{\vec r}_G = -L\ddot\theta\hat k - L\dot\theta^2\hat\imath$$

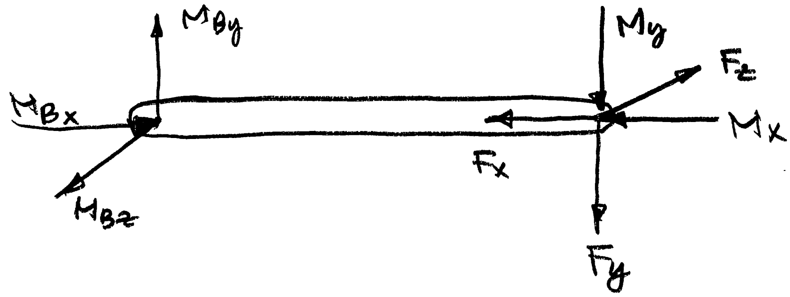
$$[\vec F = m\ddot{\vec r}_G]$$

$\hat\imath$: $F_x = -mL\dot\theta^2$

$\hat\jmath$: $F_y - mg = 0 \Rightarrow F_y = mg$

$\hat k$: $F_z = -mL\ddot\theta$

Now draw a FBD of the rod



$$M_{Bx} - M_x = 0$$

$$\boxed{M_{Bx} = \frac{mR^2}{2}\dot{\theta}\Omega}$$

$$M_{By} - M_y + F_z L = 0$$

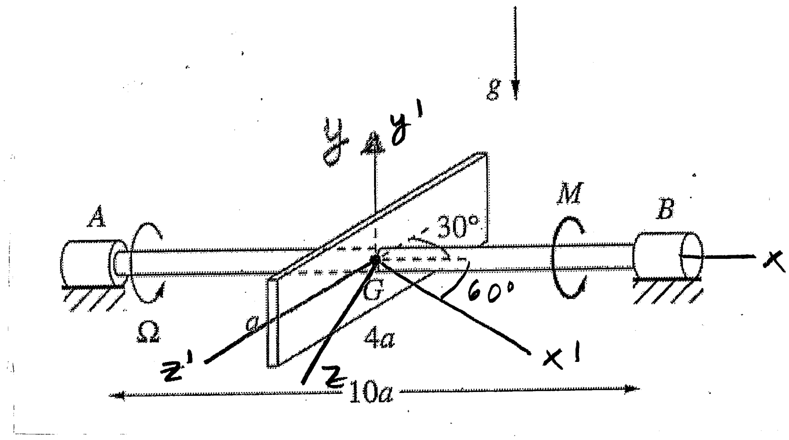
$$M_{By} = \frac{mR^2}{4}\ddot{\theta} + mL^2\ddot{\theta}$$

$$\boxed{M_{By} = m\left(\frac{R^2}{4} + L^2\right)\ddot{\theta}}$$

$$M_{Bz} - F_y L = 0$$

$$\boxed{M_{Bz} = mgL}$$

4)



The principal (primed) axes are shown. We know the inertia matrix in the primed frame:

$$[I'] = \frac{m}{12}\begin{bmatrix} 16a^2+a^2 & 0 & 0 \\ 0 & 16a^2 & 0 \\ 0 & 0 & a^2 \end{bmatrix} = \frac{ma^2}{12}\begin{bmatrix} 17 & 0 & 0 \\ 0 & 16 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The rotation matrix relating unprimed and primed frames is:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = [R_y(-60°)]\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} c60 & 0 & s60 \\ 0 & 1 & 0 \\ -s60 & 0 & c60 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1/2 & 0 & \sqrt{3}/2 \\ 0 & 1 & 0 \\ -\sqrt{3}/2 & 0 & 1/2 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$[I'] = [R][I][R]^T \Rightarrow [I] = [R]^T[I'][R]$$

$$[I] = ma^2\begin{bmatrix} 0.4167 & 0 & 0.5774 \\ 0 & 1.333 & 0 \\ 0.5774 & 0 & 1.0833 \end{bmatrix}$$

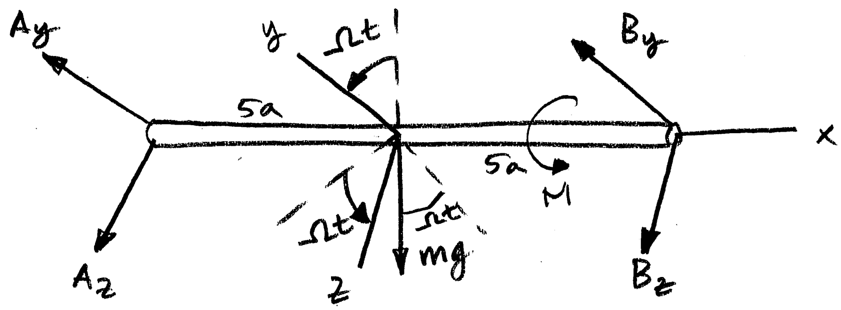
$$\Rightarrow I_{xx} = 0.4167ma^2$$

$$\vec{\omega} = \Omega\hat{i} \qquad I_{yy} = 1.333\,ma^2$$

$$\vec{\alpha} = \frac{d\vec{\omega}}{dt} = 0 \qquad I_{zz} = 1.0833\,ma^2$$

$$I_{xz} = -0.5774ma^2$$

Find resultant moment vector:



$$\vec{M} = M\hat{\imath} + 5a(A_z - B_z)\hat{\jmath} + 5a(B_y - A_y)\hat{k}$$

Special case for fixed-axis rotation:

$$x: \quad M_x = I_{xx}\alpha_x \quad \Rightarrow \quad M = 0$$

$$y: \quad M_y = -I_{xy}\alpha_x + I_{xz}\omega_x^2$$

$$5a(A_z - B_z) = -0.5774\, ma^2\Omega^2$$

$$A_z - B_z = -0.11548\, ma\Omega^2 \quad (1)$$

$$z: \quad M_z = -I_{xz}\alpha_x - I_{xy}\omega_x^2$$

$$5a(B_y - A_y) = 0 \quad \Rightarrow \quad A_y = B_y \quad (2)$$

Need more equations, sum forces.

$[\vec{F} = 0]$

$$y: \quad A_y + B_y - mg\cos\Omega t = 0$$

$$A_y + B_y = mg\cos\Omega t \quad (3)$$

$$z: \quad A_z + B_z + mg\sin\Omega t = 0$$

$$A_z + B_z = -mg\sin\Omega t \quad (4)$$

From (2) and (3):

$$2A_y = mg\cos\Omega t \Rightarrow \boxed{A_y = \frac{mg}{2}\cos\Omega t}$$

$$\Rightarrow \boxed{B_y = \frac{mg}{2}\cos\Omega t}$$

Add (1) and (4):

$$2A_z = -0.11548\, ma\Omega^2 - mg\sin\Omega t$$

$$\Rightarrow \boxed{A_z = -0.05774\, ma\Omega^2 - \frac{mg}{2}\sin\Omega t}$$

$$\boxed{A_z = -\frac{\sqrt{3}}{30}\, ma\Omega^2 - \frac{mg}{2}\sin\Omega t}$$

Subtract (1) from (4):

$$2B_z = -mg\sin\Omega t + 0.11548\, ma\Omega^2$$

$$\Rightarrow \boxed{B_z = 0.05774\, ma\Omega^2 - \frac{mg}{2}\sin\Omega t}$$

$$\boxed{B_z = \frac{\sqrt{3}}{30}\, ma\Omega^2 - \frac{mg}{2}\sin\Omega t}$$

Alternate approach: do everything in the primed frame.

$$\{\omega'\} = [R]\{\omega\} = \begin{bmatrix} 1/2 & 0 & \sqrt{3}/2 \\ 0 & 1 & 0 \\ -\sqrt{3}/2 & 0 & 1/2 \end{bmatrix} \begin{bmatrix} \Omega \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \Omega/2 \\ 0 \\ -\sqrt{3}\Omega/2 \end{bmatrix}$$

$$\{\alpha'\} = 0$$

$$\{M'\} = \begin{bmatrix} 1/2 & 0 & \sqrt{3}/2 \\ 0 & 1 & 0 \\ -\sqrt{3}/2 & 0 & 1/2 \end{bmatrix} \begin{bmatrix} M \\ 5a(A_z - B_z) \\ 5a(B_y - A_y) \end{bmatrix}$$

$$\{M'\} = \begin{bmatrix} M/2 + 5\sqrt{3}/2\, a(B_y - A_y) \\ 5a(A_z - B_z) \\ -\sqrt{3}/2\, M + 5/2\, a(B_y - A_y) \end{bmatrix}$$

Apply Euler's equations:

$$x': I'_{xx}\alpha'_x - (I'_{yy} - I'_{zz})\omega'_y\omega'_z = M_x'$$

$$\Rightarrow M = 0$$

$$y': I'_{yy}\alpha'_y - (I'_{zz} - I'_{xx})\omega'_x\omega'_z = M_y'$$

$$-\left(\frac{ma^2}{12} - \frac{17ma^2}{12}\right)\frac{\Omega}{2}\left(-\frac{\sqrt{3}\Omega}{2}\right) = 5a(A_z - B_z)$$

$$-\frac{16ma^2}{12}\frac{\sqrt{3}\Omega^2}{4} = 5a(A_z - B_z)$$

$$-\frac{\sqrt{3}ma^2\Omega^2}{3} = 5a(A_z - B_z)$$

$$\Rightarrow A_z - B_z = -0.1154 8ma\Omega^2 \quad \text{(same as 1)}$$

$z': \; I'_{zz}\alpha'_z - (I'_{xx} - I'_{yy})\omega'_x \omega'_y = M'_z$

$$0 = -\frac{\sqrt{3}}{2}\cancel{M} + \frac{5a}{2}(B_y - A_y)$$

$$\Rightarrow A_y = B_y \quad \text{(same as ②)}$$

$\Rightarrow$ We get the same results using the principal axes!