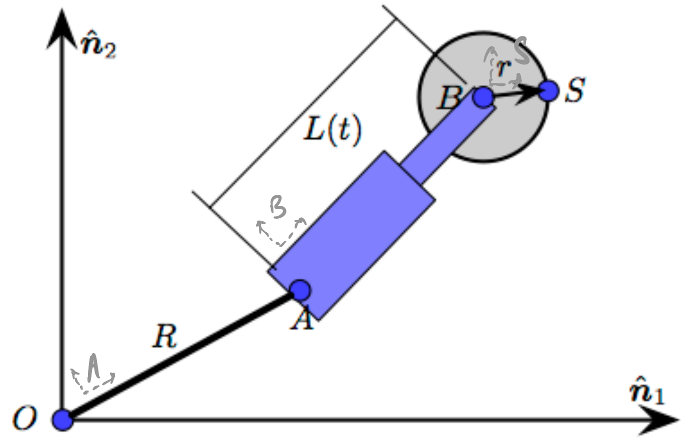
Q1)



$N: \{O, \hat{n}_1, \hat{n}_2, \hat{n}_3\}$
$A: \{O, \hat{a}_1, \hat{a}_2, \hat{n}_3\}$
$B: \{A, \hat{b}_1, \hat{b}_2, \hat{n}_3\}$
$S: \{B, \hat{s}_1, \hat{s}_2, \hat{n}_3\}$

- R & r is const.

- $\left.\begin{aligned} \vec{\omega}_{A/O} &= \dot{\alpha}\,\hat{n}_3 \\ \vec{\omega}_{B/O} &= \dot{\beta}\,\hat{n}_3 \\ \vec{\omega}_{S/B} &= \dot{\theta}\,\hat{n}_3 \end{aligned}\right\}$ Assuming +ve spin direction

  ↳ const. rate

  ↳ $\vec{\omega}_{S/O} = \vec{\omega}_{S/B} + \vec{\omega}_{B/O} = (\dot{\theta} + \dot{\beta})\,\hat{n}_3$

i) Determine Inertial vel. of Point S,

$$\vec{r}_{S/O} = R\,\hat{a}_1 + L(t)\,\hat{b}_1 + r\,\hat{s}_1$$

$$\vec{V}_{S/O} = \frac{{}^N d}{dt}\vec{r}_{S/O} = \cancelto{0}{\frac{{}^A d}{dt}(R\hat{a}_1)} + (\vec{\omega}_{A/O} \times R\hat{a}_1)$$

$$+ \frac{{}^B d}{dt}(L(t)\,\hat{b}_1) + (\vec{\omega}_{B/O} \times L(t)\,\hat{b}_1)$$

$$+ \cancelto{0}{\frac{{}^S d}{dt}(r\,\hat{s}_1)} + (\vec{\omega}_{S/O} \times r\,\hat{s}_1)$$

$$= R\dot{\alpha}\,\hat{a}_2 + \dot{L}(t)\,\hat{b}_1 + L(t)\dot{\beta}\,\hat{b}_2 + r(\dot{\theta} + \dot{\beta})\,\hat{s}_2$$

ii) Determine Inertial Accel. of S,

$$\vec{V}_{S/O} = R\dot{\alpha}\,\hat{a}_2 + \dot{L}(t)\,\hat{b}_1 + L(t)\dot{\beta}\,\hat{b}_2 + r(\dot{\theta} + \dot{\beta})\,\hat{s}_2$$

$$\vec{a}_{S/O} = \frac{{}^N d}{dt}\vec{V}_{S/O} = \frac{{}^A d}{dt}(R\dot{\alpha}\,\hat{a}_2) + (\vec{\omega}_{A/O} \times R\dot{\alpha}\,\hat{a}_2)$$

$$+ \frac{{}^B d}{dt}(\dot{L}(t)\,\hat{b}_1) + (\vec{\omega}_{B/O} \times \dot{L}(t)\,\hat{b}_1)$$

$$+ \frac{{}^B d}{dt}(L(t)\dot{\beta}\,\hat{b}_2) + (\vec{\omega}_{B/O} \times L(t)\dot{\beta}\,\hat{b}_2)$$

$$+ \frac{{}^S d}{dt}(r(\dot{\theta} + \dot{\beta})\,\hat{s}_2) + (\vec{\omega}_{S/O} \times r(\dot{\theta} + \dot{\beta})\,\hat{s}_2)$$

$$\begin{aligned} = \; & R\ddot{\alpha}\,\hat{a}_2 + (-R\dot{\alpha}^2\,\hat{a}_1) \\ & + \ddot{L}(t)\,\hat{b}_1 + (\dot{L}(t)\dot{\beta}\,\hat{b}_2) \\ & + (\dot{L}(t)\dot{\beta} + L(t)\ddot{\beta})\,\hat{b}_2 + (-L(t)\dot{\beta}^2\,\hat{b}_1) \\ & + (r(\cancel{\ddot{\theta}} + \ddot{\beta})\,\hat{s}_2) + (-r(\dot{\theta} + \dot{\beta})^2\,\hat{s}_1) \end{aligned}$$

$$\begin{aligned} = \; & -R\dot{\alpha}^2\,\hat{a}_1 + R\ddot{\alpha}\,\hat{a}_2 \\ & + (\ddot{L}(t) - L(t)\dot{\beta}^2)\,\hat{b}_1 + (2\dot{L}(t)\dot{\beta} + L(t)\ddot{\beta})\,\hat{b}_2 \\ & - r(\dot{\theta} + \dot{\beta})^2\,\hat{s}_1 + r\ddot{\beta}\,\hat{s}_2 \end{aligned}$$

iii) Determine vel. of A w.r.t. S,

$$\vec{r}_{A/S} = -r\,\hat{s}_1 - L(t)\,\hat{b}_1$$

$$\vec{V}_{A/S} = \frac{{}^S d}{dt}\vec{r}_{A/S} = \cancel{\frac{{}^S d}{dt}(-r\,\hat{s}_1)}^{\,0} - \left[\frac{{}^B d}{dt}(L(t)\,\hat{b}_1) + (\vec{\omega}_{B/S} \times L(t)\,\hat{b}_1)\right]$$

$$= -(\dot{L}(t)\,\hat{b}_1 + (\vec{\omega}_{B/S} \times L(t)\,\hat{b}_1)) \quad , \quad \vec{\omega}_{B/S} = -\vec{\omega}_{S/B} = -\dot{\theta}\,\hat{n}_3$$

$$= -(\dot{L}(t)\,\hat{b}_1 - L(t)\,\dot{\theta}\,\hat{b}_2)$$

$$= -\dot{L}(t)\,\hat{b}_1 + L(t)\,\dot{\theta}\,\hat{b}_2 \quad \#$$