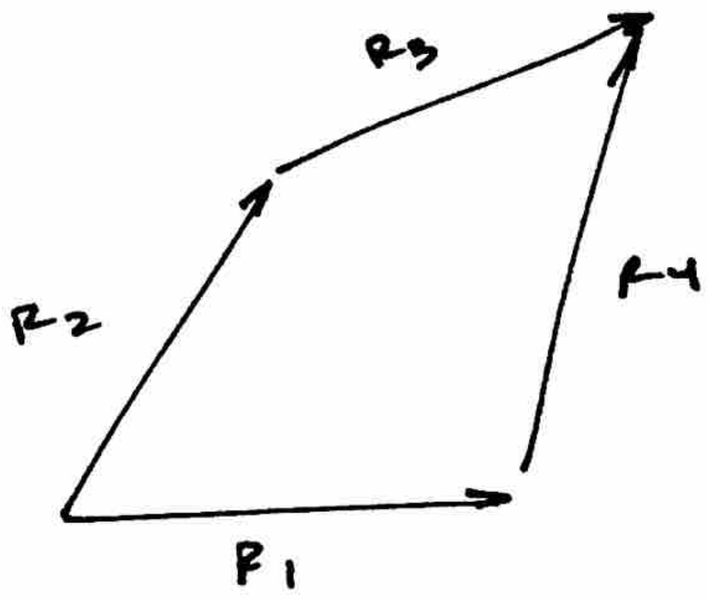
LAB 6
HAND CALCULATIONS



$$R_2 + R_3 = R_1 + R_4$$

$$0 = R_1 + R_4 - R_2 - R_3$$

① $\hat{i}: 0 = R_1 + R_4 C_4 - R_2 C_2 - R_3 C_3$

② $\hat{j}: 0 = R_4 S_4 - R_2 S_2 - R_3 S_3$

$$\frac{d}{dt}\begin{pmatrix}① \\ ②\end{pmatrix} \quad \begin{aligned} 0 &= -R_4 S_4 \dot{\theta}_4 + R_2 S_2 \dot{\theta}_2 + R_3 S_3 \dot{\theta}_3 \\ 0 &= R_4 C_4 \dot{\theta}_4 - R_2 C_2 \dot{\theta}_2 - R_3 C_3 \dot{\theta}_3 \end{aligned}$$

$$\frac{d}{dt}\begin{pmatrix}\dot{①} \\ \dot{②}\end{pmatrix} \quad \begin{aligned} 0 &= -R_4 C_4 \dot{\theta}_4^2 - R_4 S_4 \ddot{\theta}_4 + R_2 C_2 \dot{\theta}_2^2 + R_3 C_3 \dot{\theta}_3^2 + R_3 S_3 \ddot{\theta}_3 \\ 0 &= -R_4 S_4 \dot{\theta}_4^2 + R_4 C_4 \ddot{\theta}_4 + R_2 S_2 \dot{\theta}_2^2 + R_3 S_3 \dot{\theta}_3^2 - R_3 C_3 \ddot{\theta}_3 \end{aligned}$$

$$\begin{pmatrix}\ddot{①} \\ \ddot{②}\end{pmatrix} \quad \begin{aligned} R_4 S_4 \ddot{\theta}_4 - R_3 S_3 \ddot{\theta}_3 &= -R_4 C_4 \dot{\theta}_4^2 + R_2 C_2 \dot{\theta}_2^2 + R_3 C_3 \dot{\theta}_3^2 \\ -R_4 C_4 \ddot{\theta}_4 + R_3 C_3 \ddot{\theta}_3 &= -R_4 S_4 \dot{\theta}_4^2 + R_2 S_2 \dot{\theta}_2^2 + R_3 S_3 \dot{\theta}_3^2 \end{aligned}$$

③ $\hat{i}: \bar{x}_2 = \frac{1}{2} R_2 C_2$

④ $\hat{j}: \bar{y}_2 = \frac{1}{2} R_2 S_2$

$\frac{d}{dt}$ (③, ④) $\quad \dot{\bar{x}}_2 = -\frac{1}{2} R_2 S_2 \dot{\theta}_2$

$\dot{\bar{y}}_2 = \frac{1}{2} R_2 C_2 \dot{\theta}_2$

$\frac{d}{dt}$ ($\dot{③}$, $\dot{④}$) $\quad \ddot{\bar{x}}_2 = -\frac{1}{2} R_2 C_2 \dot{\theta}_2^2$

$\ddot{\bar{y}}_2 = -\frac{1}{2} R_2 S_2 \dot{\theta}_2^2$

$\ddot{③}$ $\quad \ddot{\bar{x}}_2 = -\frac{1}{2} R_2 C_2 \dot{\theta}_2^2$

$\ddot{④}$ $\quad \ddot{\bar{y}}_2 = -\frac{1}{2} R_2 S_2 \dot{\theta}_2^2$

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⑤ $\hat{i}: \bar{x}_3 = R_2 C_2 + \frac{1}{2} R_3 C_3$

⑥ $\hat{j}: \bar{y}_3 = R_2 S_2 + \frac{1}{2} R_3 S_3$

$\frac{d}{dt}$ (⑤, ⑥) $\quad \dot{\bar{x}}_3 = -R_2 S_2 \dot{\theta}_2 - \frac{1}{2} R_3 S_3 \dot{\theta}_3$

$\dot{\bar{y}}_3 = R_2 C_2 \dot{\theta}_2 + \frac{1}{2} R_3 C_3 \dot{\theta}_3$

$\frac{d}{dt}$ ($\dot{⑤}$, $\dot{⑥}$) $\quad \ddot{\bar{x}}_3 = -R_2 C_2 \dot{\theta}_2^2 - \frac{1}{2} R_3 S_3 \dot{\theta}_3^2 - \frac{1}{2} R_3 S_3 \ddot{\theta}_3$

$\ddot{\bar{y}}_3 = -R_2 S_2 \dot{\theta}_2^2 - \frac{1}{2} R_3 S_3 \dot{\theta}_3^2 + \frac{1}{2} R_3 C_3 \ddot{\theta}_3$

$\ddot{⑤}$ $\quad$ [redacted] $\frac{1}{2} R_3 S_3 \ddot{\theta}_3 + \ddot{\bar{x}}_3 = -R_2 C_2 \dot{\theta}_2^2 - \frac{1}{2} R_3 S_3 \dot{\theta}_3^2$

$\ddot{⑥}$ $\quad$ [redacted] $-\frac{1}{2} R_3 S_3 + \ddot{\bar{y}}_3 = -R_2 S_2 \dot{\theta}_2^2 - \frac{1}{2} R_3 S_3 \dot{\theta}_3^2$

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⑦ $\bar{x}_4 = R_1 + \frac{1}{2} R_4 C_4$

⑧ $\bar{y}_4 = \frac{1}{2} R_4 S_4$

$\frac{d}{dt}$ (⑦, ⑧) $\quad \dot{\bar{x}}_4 = \frac{1}{2} R_4 S_4 \dot{\theta}_4$

$\dot{\bar{y}}_4 = \frac{1}{2} R_4 C_4 \dot{\theta}_4$

$\frac{d}{dt}$ ($\dot{⑦}$, $\dot{⑧}$) $\quad \ddot{\bar{x}}_4 = -\frac{1}{2} R_4 C_4 \dot{\theta}_4^2 - \frac{1}{2} R_4 S_4 \ddot{\theta}_4$

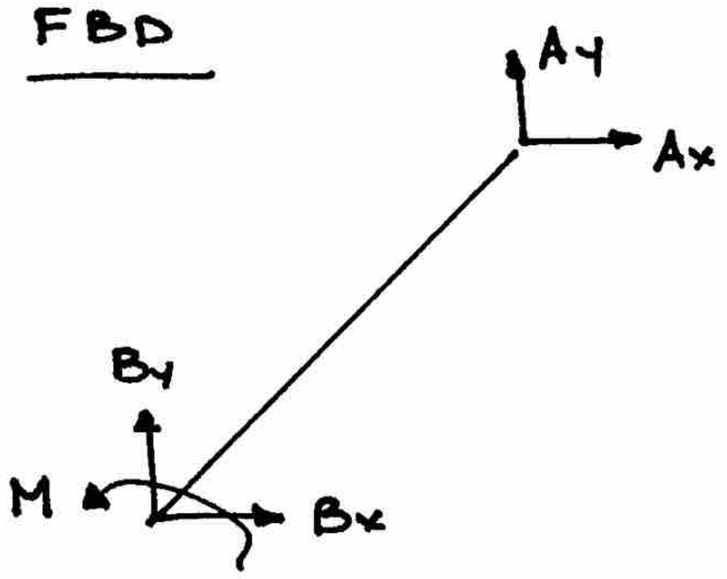
$\ddot{\bar{y}}_4 = -\frac{1}{2} R_4 S_4 \dot{\theta}_4^2 + \frac{1}{2} R_4 S_4 \ddot{\theta}_4$

$\ddot{⑦}$ $\quad \frac{1}{2} R_4 S_4 \ddot{\theta}_4 + \ddot{\bar{x}}_4 = -\frac{1}{2} R_4 C_4 \dot{\theta}_4^2$

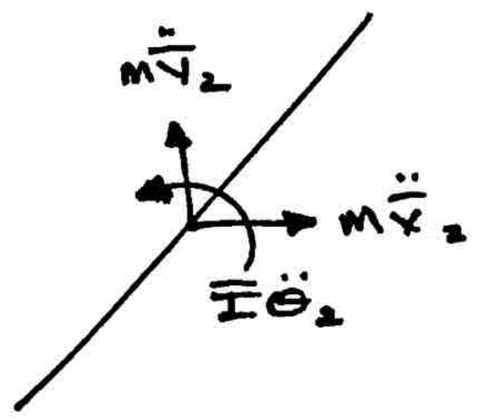
$\ddot{⑧}$ $\quad -\frac{1}{2} R_4 C_4 \ddot{\theta}_4 + \ddot{\bar{y}}_4 = -\frac{1}{2} R_4 S_4 \dot{\theta}_4^2$

LINK 2

FBD



KD



(9) ΣF_x: $A_x + B_x = m_2\ddot{\bar{x}}_2$

(10) ΣF_y: $A_y + B_y = m_2\ddot{\bar{y}}_2$

(11) ΣM: $M - A_x\frac{R_2}{2}S_2 + A_y\frac{R_2}{2}C_2 + B_x\frac{R_2}{2}S_2 - B_y\frac{R_2}{2}C_2 = I\ddot{\theta}_2$

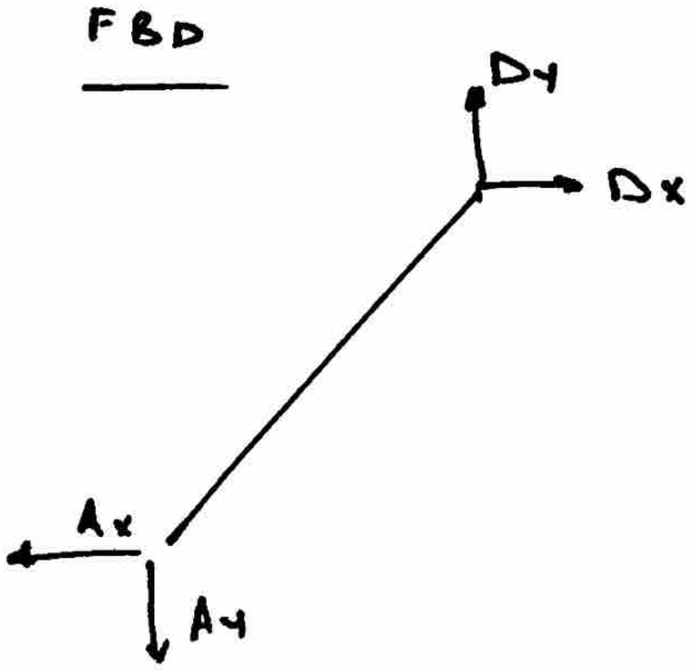
(9) $m_2\ddot{\bar{x}}_2 - A_x - B_y = 0$

(10) $m_2\ddot{\bar{y}}_2 - A_y - B_y = 0$

(11) $\frac{1}{2}R_2S_2A_x - \frac{1}{2}R_2C_2A_y - \frac{1}{2}R_2S_2B_x + \frac{1}{2}R_2C_2B_y - M = 0$

LINK 3

FBD



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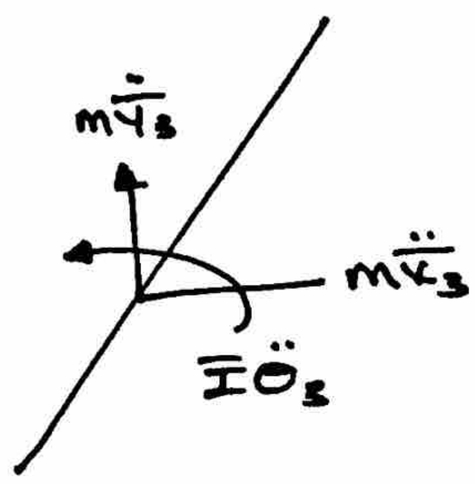


(12) ΣF_x: $-A_x + D_x = m_3\ddot{\bar{x}}$

(13) ΣF_y: $-A_y + D_y = m\ddot{\bar{y}}$

(14) ΣM: $-A_x\frac{R_3}{2}S_3 + A_y\frac{R_3}{2}C_3 - D_x\frac{R_3}{2}S_3 + D_y\frac{R_3}{2}C_3 = \bar{I}\ddot{\theta}_3$

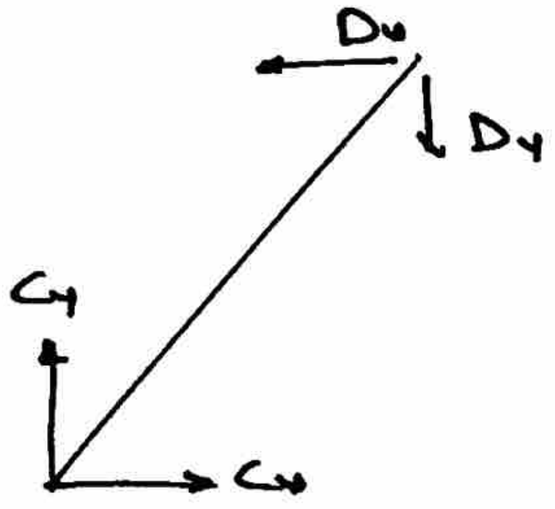
(12) $m_3\ddot{\bar{x}} + A_x - D_x = 0$

(13) $m_3\ddot{\bar{y}} + A_y - D_y = 0$

(14) $\bar{I}_3\ddot{\theta}_3 + \frac{1}{2}R_3S_3A_x - \frac{1}{2}R_3C_3A_y + \frac{1}{2}R_3S_3D_x - \frac{1}{2}R_3C_3D_y$

LINK 4

FBD



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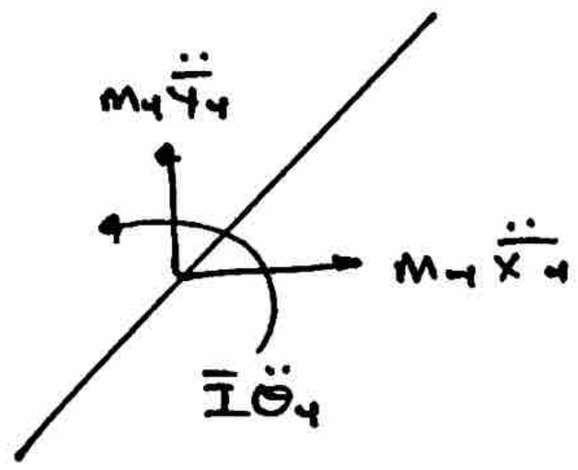

(15) $\Sigma F_x: C_x - D_x = m_4 \ddot{\bar{x}}_4$

(16) $\Sigma F_y: C_y - D_y = m_4 \ddot{\bar{y}}_4$

(17) $\Sigma M: C_x \frac{R_4}{2} S - C_y \frac{R_4}{2} C_4 + D_x \frac{R_4}{2} S_4 - D_y \frac{R_4}{2} C_4 = \bar{I} \ddot{\theta}_4$

(15) $m_4 \ddot{\bar{x}}_4 - C_x + D_x = 0$

(16) $m_4 \ddot{\bar{y}}_4 - C_y + D_y = 0$

(17) $\bar{I} \ddot{\theta}_4 - \frac{1}{2} R_4 S_4 C_x + \frac{1}{2} R_4 C_4 C_y - \frac{1}{2} R_4 S_4 D_x + \frac{1}{2} R_4 C_4 D_y = 0$