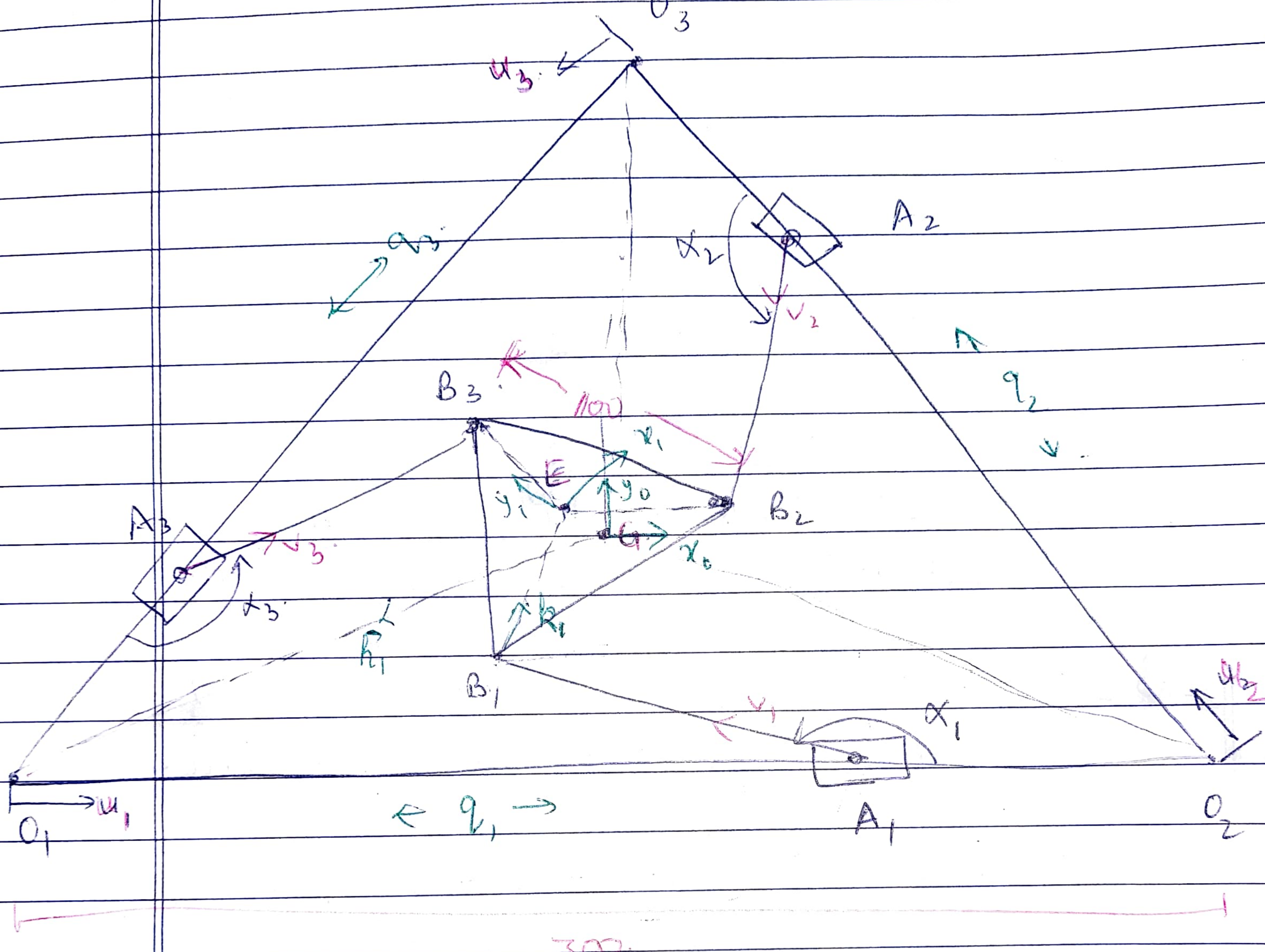


$O_1G = O_2G = O_3G = R$

$A_1B_1 = A_2B_2 = A_3B_3 = 100 = l.$

$EB_1 = EB_2 = EB_3 = r$

Config. vector : , q_1, q_2, q_3 $\Rightarrow$ prismatic joints.

a) Points B_1, B_2, B_3 wrt G.

We know pt. E, we can write point B_1 as.

$$^{E}T_{B_1} = \begin{bmatrix} 1 & 0 & 0 & rc210^\circ \\ 0 & 1 & 0 & rs210^\circ \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^{E}T_{B_2} = \begin{bmatrix} 1 & 0 & 0 & rc90^\circ \\ 0 & 1 & 0 & rs90^\circ \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad ^{E}T_{B_3} = \begin{bmatrix} 1 & 0 & 0 & rc(-30) \\ 0 & 1 & 0 & rs(-30) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^{G}T_{B_1} = {^{G}T_E}\, {^{E}T_{B_1}} \quad \checkmark$$

b) $$^{G}T_{O_1} = \begin{bmatrix} I_{3\times3} & \begin{matrix} Rc(210) \\ Rs(210) \\ 0 \end{matrix} \\ O_{1\times3} & 1 \end{bmatrix} \qquad ^{G}T_{O_2} = \begin{bmatrix} I_{3\times3} & \begin{matrix} Rc90 \\ Rs90 \\ 0 \end{matrix} \\ O_{1\times3} & 1 \end{bmatrix}$$

$$^{G}T_{O_3} = \begin{bmatrix} I_{3\times3} & \begin{matrix} Rc(-30) \\ Rs(-30) \\ 0 \end{matrix} \\ O_{1\times3} & 1 \end{bmatrix}$$

c) $$^{O_1}T_{A_1} = \begin{bmatrix} I_{3\times3} & \begin{matrix} q_1 \\ 0 \\ 0 \end{matrix} \\ O_{1\times3} & 1 \end{bmatrix}$$

$$^{O_2}T_{A_2} = \begin{bmatrix} I_{3\times3} & \begin{matrix} q_2\, c120 \\ q_2\, s120 \\ 0 \end{matrix} \\ O_{1\times3} & 1 \end{bmatrix}$$

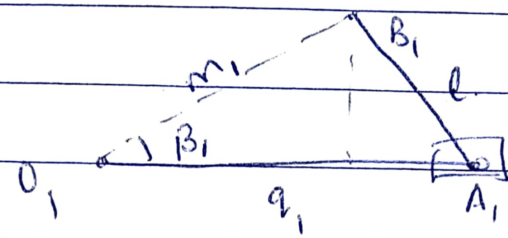
$$^{O_3}T_{A_3} = \begin{bmatrix} I_{3\times3} & \begin{matrix} q_3\, c240 \\ q_3\, s240 \\ 0 \end{matrix} \\ O_{1\times3} & 1 \end{bmatrix}$$

$$^{G}T_{A_1} = {^{G}T_{O_1}}\, {^{O_1}T_{A_1}} \qquad ^{G}T_{A_2} = {^{G}T_{O_2}}\, {^{O_2}T_{A_2}}; \quad ^{G}T_{A_3} = {^{G}T_{O_3}}\, {^{O_3}T_{A_3}}$$

∴ We know all positions, pt. G, E, B_1, B_2, B_3, O_1, O_2, O_3 and A_1, A_2 and A_3 with the prismatic joints in terms of q_1, q_2, q_3.

Let us consider one by one :-

① $O_1 A_1 B_1$



$\|O_1 B_1\|_2 = m_1$ (distance b/w O_1 and B_1)

$$\beta_1 = \tan^{-1}\left(\frac{B_{1y} - O_{1y}}{B_{1x} - O_{1x}}\right)$$

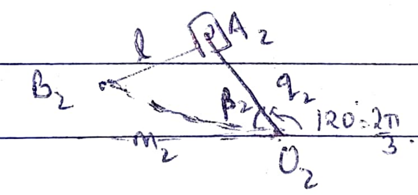
Applying cosine rule :- $l^2 = m^2 + q_1^2 - 2m_1 q_1 \cos\beta_1$

$\therefore q_1^2 - 2m_1 q_1 \cos\beta_1 + (m_1^2 - l^2) = 0$

$\therefore$ Quadratic equation $\Rightarrow$ $q_1 = \dfrac{\cancel{B}\ 2m_1\cos\beta_1 \pm \sqrt{(2m_1\cos\beta_1)^2 - 4(m^2 - l^2)}}{2}$

Here, we know m_1, β_1 and l. We can find q_1

Similarly,

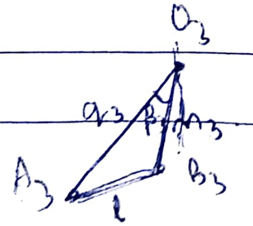


$m_2 = \|O_2 B_2\|_2$.

$$\beta_2 = \frac{\pi}{3} - \tan^{-1}\left(\frac{B_{2y} - O_{2y}}{B_{2x} - O_{2x}}\right)$$

$q_2^2 - 2m_2 q_2 \cos\beta_2 + (m_2^2 - l^2) = 0$.

& lastly



$m_3 = \|O_3 B_3\|_2$. $\beta_3 = \cancel{\frac{\pi}{6}}$ ~~can be found~~.

$q_3^2 - 2m_3 q_3 \cos\beta_3 + (m_3^2 - l^2) = 0$.