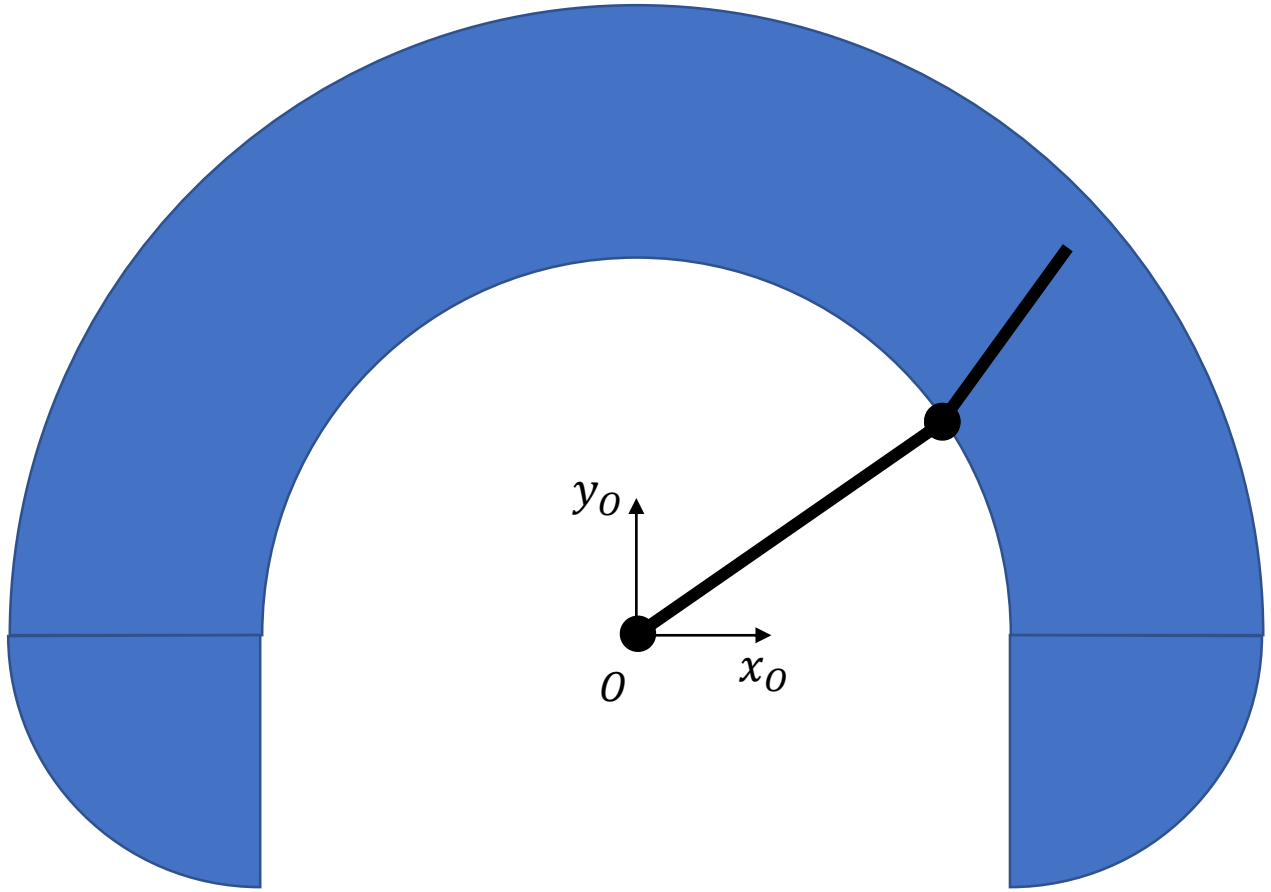
H.W. #3

❖ **Submit *a pdf file* via email by next Monday 6 p.m.**

1. There is a 2-link planar manipulator. [5.0]
   1) Draw reachable workspace when $L_1 > L_2$, $0 \leq \theta_1 \leq 180°$ and $-90° \leq \theta_2 \leq 90°$. [2.5]



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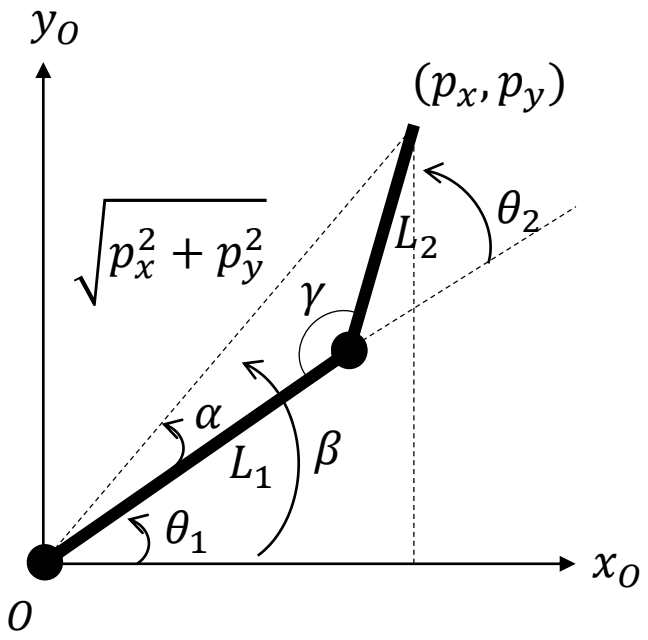
2) Given a position of the manipulator's tip as (p_x, p_y), find a solution using a geometric method. [2.5]
(hint: Apply the "law of cosines")



(1) $\gamma = \pi - \theta_2$

$$p_x^2 + p_y^2 = L_1^2 + L_2^2 - 2L_1^2L_2^2\cos(\gamma) = L_1^2 + L_2^2 + 2L_1^2L_2^2\cos(\theta_2)$$

$$\cos(\theta_2) = \frac{p_x^2 + p_y^2 - L_1^2 - L_2^2}{2L_1^2L_2^2}$$

$$\therefore \theta_2 = atan2(\pm\sqrt{1 - \cos^2(\theta_2)}, \cos(\theta_2))$$

(2) $\theta_1 = \beta \pm \alpha$, where the plus sign is used if $\theta_2 < 0$
and the minus sign if $\theta_2 > 0$.

$$\beta = atan2(p_y, p_x)$$

$$L_2^2 = L_1^2 + p_x^2 + p_y^2 - 2L_1\sqrt{p_x^2 + p_y^2}\cos(\alpha)$$

$$\cos(\alpha) = \frac{p_x^2 + p_y^2 + L_1^2 - L_2^2}{2L_1\sqrt{p_x^2 + p_y^2}}$$

$$\therefore \theta_1 = atan2(p_y, p_x) \pm atan2(\sqrt{1 - \cos^2(\alpha)}, \cos(\alpha))$$

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2. In “Fwd_Kine.nxc” used during Lab #2, add an algorithm to restrict joint angles. For example, if joint angles meet the limits while increasing them, keep the limited angles regardless of increasing joint angles. [5.0]

- Here are joint angle limits, $0 \leq \theta_1 \leq 180°$ and $-90° \leq \theta_2 \leq 90°$.
- A video clip should include increasing joint angles in a NXT LCD.
- **Submit a source code with a video clip link like a youtube link or cloud link, or a compressed video clip file.**