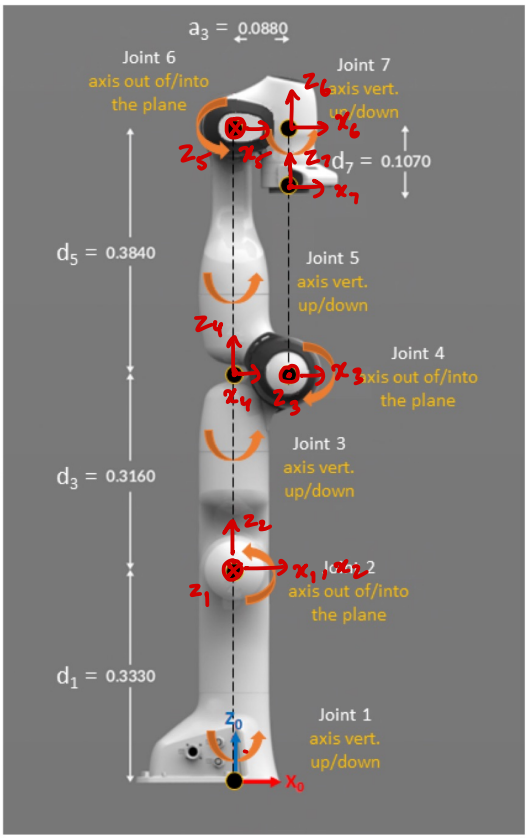
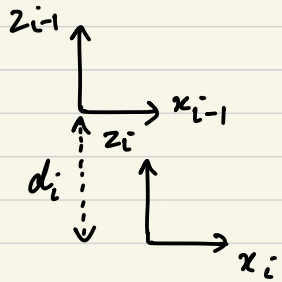
MODELING - HW3

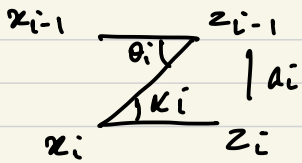
1.



⊗ - out of plane

⊙ - inside the plane





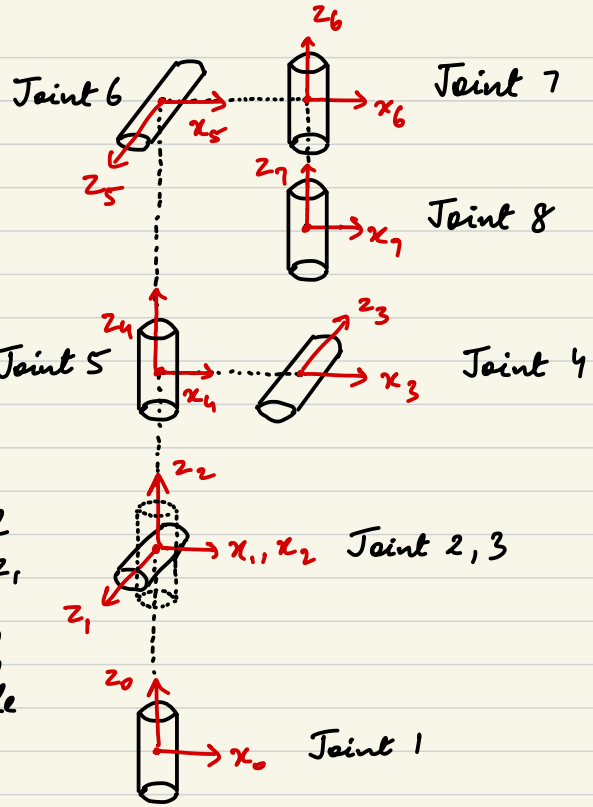
Constraints:

- $x_1 \perp z_0$ ✓
- $x_2 \perp z_1$ ✓
- $x_3 \perp z_2$ ✓
- $x_4 \perp z_3$ ✓
- $x_5 \perp z_4$ ✓
- $x_6 \perp z_5$ ✓
- $x_7 \perp z_6$ ✓

Franka Emika Panda Cobot

D-H Parameter Table

	α	θ	d	a
$0 \to 1$	$\pi/2$	θ_1	d_1	0
$1 \to 2$	$-\pi/2$	θ_2	0	0
$2 \to 3$	$-\pi/2$	θ_3	d_3	a_3
$3 \to 4$	$\pi/2$	θ_4	0	$-a_3$
$4 \to 5$	$\pi/2$	θ_5	d_5	0
$5 \to 6$	$-\pi/2$	θ_6	0	a_3
$6 \to 7$	0	θ_7	$-d_7$	0



- Shifting origin of joint 3 to joint 2 to coincide x_2 and z_1
- Shifting origin of joint 5 to coincide x_4 and z_3

$$A_i = \text{Rot}_{z,\theta_i}\,\text{Trans}_{z,d_i}\,\text{Trans}_{x,a_i}\,\text{Rot}_{x,\alpha_i}$$

$$= \begin{bmatrix} c_{\theta_i} & -s_{\theta_i} & 0 & 0 \\ s_{\theta_i} & c_{\theta_i} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & a_i \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & c_{\alpha_i} & -s_{\alpha_i} & 0 \\ 0 & s_{\alpha_i} & c_{\alpha_i} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta_i S\alpha_i & a_i C\theta_i \\ S\theta_i & C\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

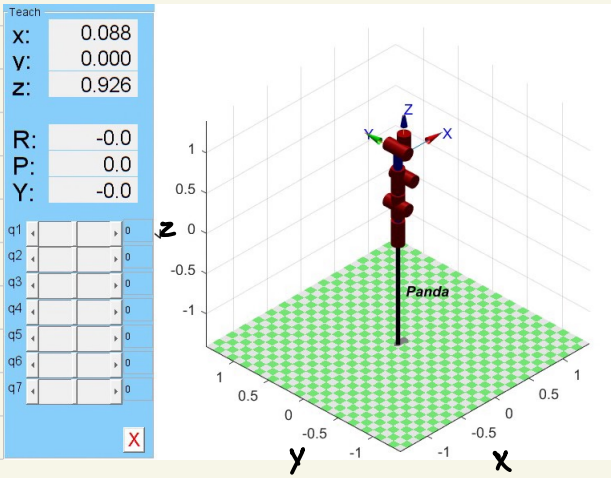
Position of end-effector is given by:

$$T_7^0 = A_1 A_2 A_3 A_4 A_5 A_6 A_7$$

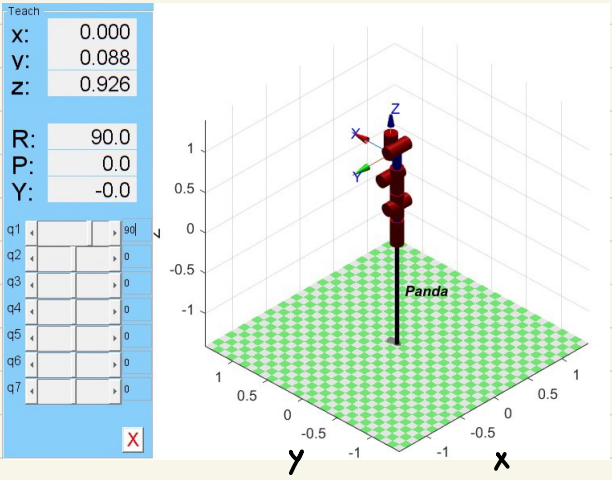
When all joint angles are zero:

$$T_7^0 = \begin{bmatrix} 1 & 0 & 0 & 0.088 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0.926 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

All $\theta = 0^\circ$

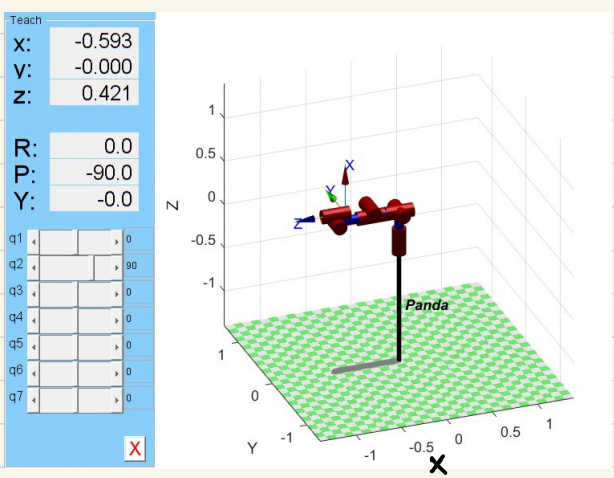


$\theta_1 = 90°$



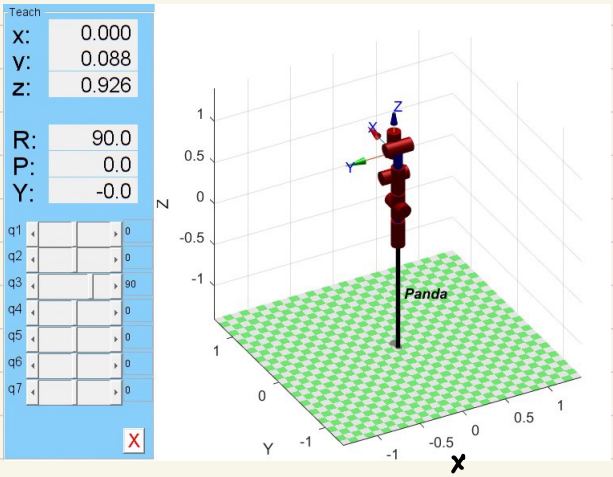
$$T = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0.088 \\ 0 & 0 & 1 & 0.926 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$\theta_2 = 90°$



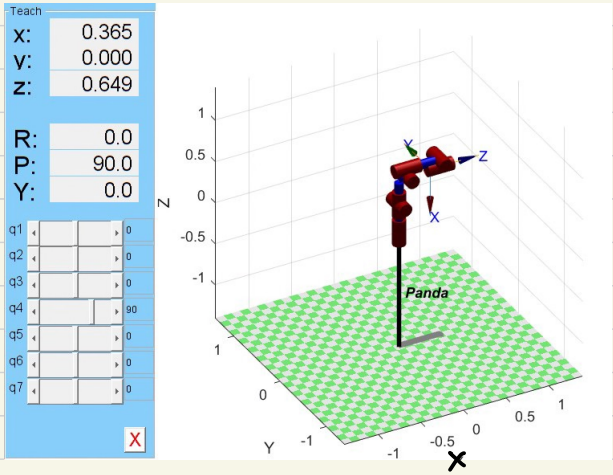
$$T = \begin{bmatrix} 0 & 0 & -1 & -0.593 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0.421 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$\theta_3 = 90^\circ$



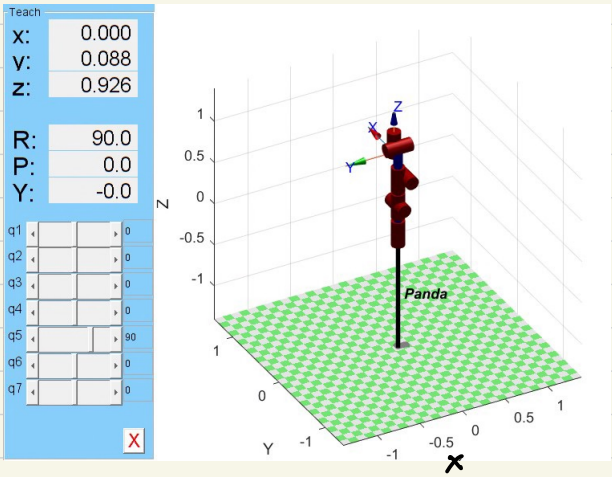
$$T = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0.088 \\ 0 & 0 & 1 & 0.926 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$\theta_4 = 90^\circ$



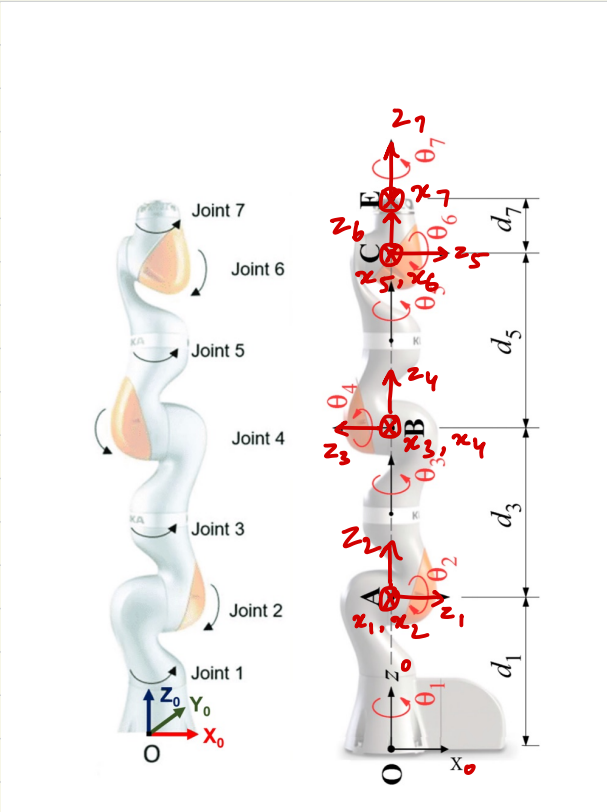
$$T = \begin{bmatrix} 0 & 0 & 1 & 0.365 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0.649 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\theta_5 = 90^\circ$$



$$T = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0.088 \\ 0 & 0 & 1 & 0.926 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

2.



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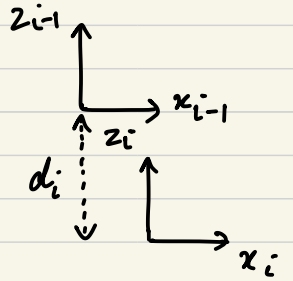
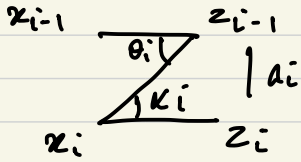
$x_4 \perp \cap z_3$ ✓

$x_5 \perp \cap z_4$ ✓

$x_6 \perp \cap z_5$ ✓

Assigning coordinate frames by shifting origins





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$3 \to 4$	$-\pi/2$	θ_4	0	0
$4 \to 5$	$-\pi/2$	θ_5	d_5	0
$5 \to 6$	$\pi/2$	θ_6	0	0
$6 \to 7$	0	θ_7	d_7	0