Homework – Forward Kinematics

Recall that for a 2-link planar manipulator the end-effector (EE) p has the position (x_{p0}, y_{p0}):

$$x_{p0} = l_1 \cos\theta_1 + l_2 \cos(\theta_1 + \theta_2)$$
$$y_{p0} = l_1 \sin\theta_1 + l_2 \sin(\theta_1 + \theta_2) \quad (1)$$

For both 1 and 2 provide the following

a. All files (e.g. NXC and Headers). Comment and make readable (e.g. good use of white space)
b. URL to your YouTube video demonstrating this program

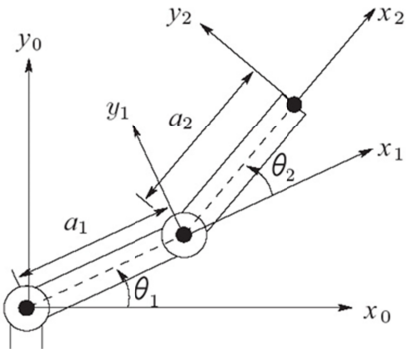
1. Show hand calculations given (1) and the values in Columns 1 and 2 to complete Column 3. Execute program with those values to complete Column 4 below (20-points).

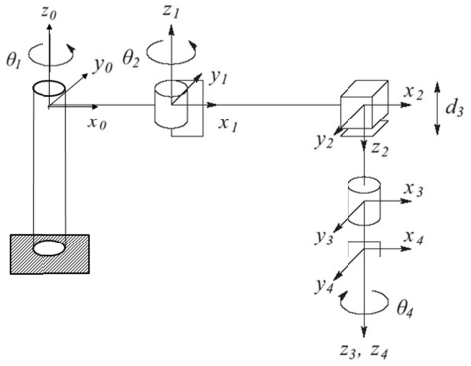
θ_1 [deg]	θ_2 [deg]	Equation (1) [studs]	Observed value [studs]
0	+90	(7, 5)	(7, 5)
0	-90		
+90	-90		
-90	-90		
+45	+45		

2. Unscrew and reverse the beams such that Link 1 is a Beam 7 and Link 2 is a Beam 9. Repeat Question 1 to complete a new table (20-points).

3. The sketch, DH parameters and arm matrix for the two-link planar arm are given in the figure below (left). Confirm by hand calculations and derivations the given ${T_2}^0$ (15-points).

4. The sketch, DH parameters and arm matrix for the SCARA arm are given below (right). Confirm by hand calculations and derivations the given ${T_4}^0$ (15-points).





Link	a_i	α_i	d_i	θ_i
1	a_1	α_1	d_1	θ_1
2	a_2	α_2	d_2	θ_2

$${T_2}^0 = \begin{bmatrix} c_{12} & -s_{12} & 0 & a_1c_1 + a_2c_{12} \\ s_{12} & c_{12} & 0 & a_1s_1 + a_2s_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Link	a_i	α_i	d_i	θ_i
1	a_1	0	0	${\theta^*}_1$
2	a_2	180	0	${\theta^*}_2$
3	0	0	${d^*}_3$	0
4	0	0	d_4	${\theta^*}_4$

* denotes variable

$${T_4}^0 = \begin{bmatrix} c_{12}c_4 + s_{12}s_4 & -c_{12}s_4 + s_{12}c_4 & 0 & a_1c_1 + a_2c_{12} \\ s_{12}c_4 - c_{12}s_4 & -s_{12}s_4 - c_{12}c_4 & 0 & a_1s_1 + a_2s_{12} \\ 0 & 0 & -1 & -d_3 - d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$