Assigned:20/10/2015
Due: 27/10/2015

Kinematics and Dynamics of Robotic Manipulators
Homework I

1. The following homogeneous coordinate transformation matrices are given.

$$T_0^1=\begin{bmatrix} C_1 & 0 & -S_1 & 0 \\ S_1 & 0 & C_1 & 0 \\ 0 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_1^2=\begin{bmatrix} C_2 & 0 & S_2 & 0 \\ S_2 & 0 & -C_2 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_2^3=\begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & q_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T_{base}^{wrist}=\begin{bmatrix} -C_1C_2 & C_1S_2 & -S_1 & q_3C_1S_2 \\ -S_1C_2 & S_1S_2 & C_1 & q_3S_1S_2 \\ S_2 & C_2 & 0 & q_3C_2+d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}=T_0^3$$

$$T_3^4=\begin{bmatrix} C_4 & 0 & S_4 & 0 \\ S_4 & 0 & -C_4 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_4^5=\begin{bmatrix} C_5 & -S_5 & 0 & 0 \\ S_5 & C_5 & 0 & 0 \\ 0 & 0 & 1 & d_5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T_{base}^{tool}=\begin{bmatrix} -C_1C_{24}C_5-S_1S_5 & C_1C_{24}S_5-S_1C_5 & -C_1S_{24} & q_3C_1S_2-d_5C_1S_{24} \\ -S_1C_{24}C_5+C_1S_5 & S_1C_{24}S_5+C_1C_5 & -S_1S_{24} & q_3S_1S_2-d_5S_1S_{24} \\ S_{24}C_5 & -S_{24}S_5 & -C_{24} & q_3C_2+d_1+d_5C_{24} \\ 0 & 0 & 0 & 1 \end{bmatrix}=T_0^5$$

   a. Find x^2 in frame 1 coordinates.
   b. Find the vector in base coordinates from the origin of the base to the origin of frame 3.
   c. Specify the tool tip, p, in frame 3 coordinates.

2. The Stanford/JPL manipulator has the following kinematic parameter table.

Joint	θ	d	a	α
1	q_1	d_1	0	$-\pi/2$
2	q_2	d_2	0	$\pi/2$
3	$-\pi/2$	q_3	0	0
4	q_4	0	0	$-\pi/2$
5	q_5	0	0	$\pi/2$
6	q_6	d_6	0	0

find the homogeneous transformation matrix T_0^1

find the homogeneous transformation matrix T_1^2

find the homogeneous transformation matrix T_1^3

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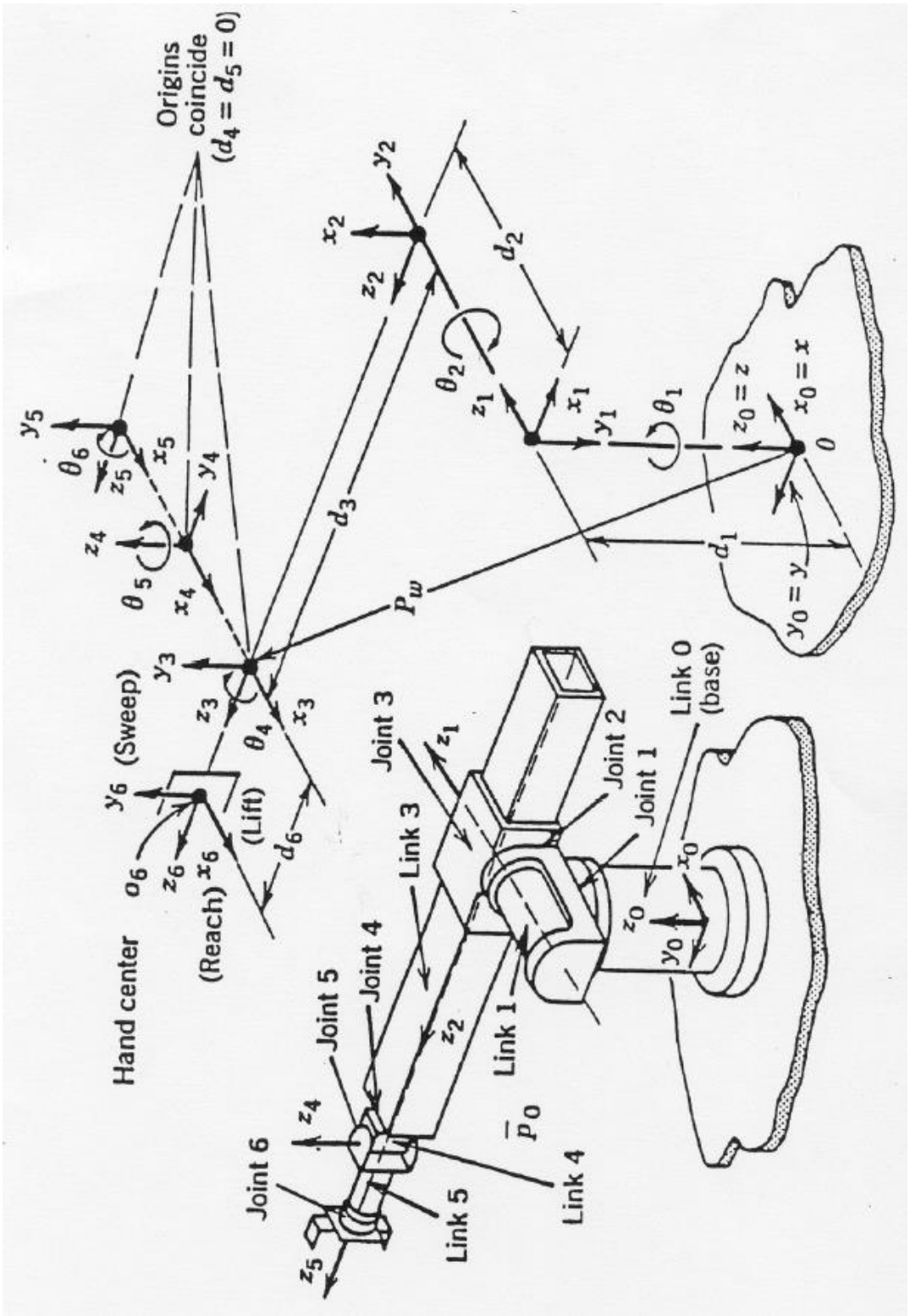

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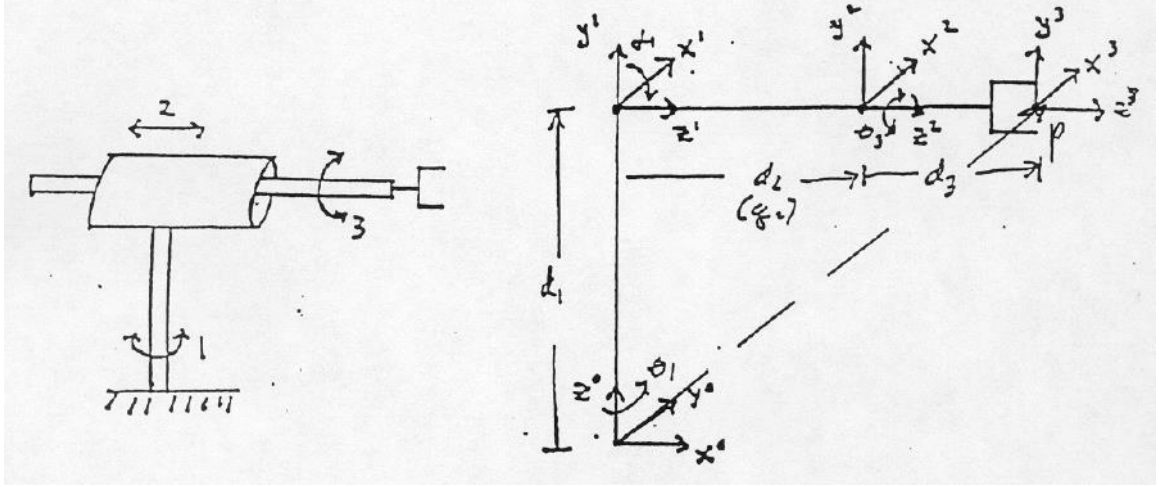
3. Below figure shows a 3 dof robot that has a revolute joint, a prismatic joint and another revolute joint providing roll for the tool. Tool to base arm matrix is given. Find the tool configuration vector. Find the inverse kinematics, i.e., q_1 , q_2 and q_3.

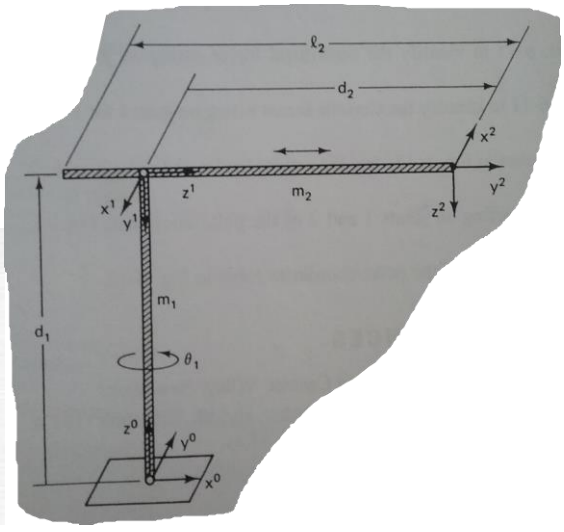
$$T_{base}^{tool} = T_0^3 = \begin{bmatrix} C_1C_3 & -C_1S_3 & S_1 & S_1(d_2+d_3) \\ S_1C_3 & -S_1S_3 & -C_1 & -C_1(d_2+d_3) \\ S_3 & C_3 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

note: $d_2 = q_2$



4. A two axis polar coordinate robot is given on figure. It has following homogeneous coordinate transformation matrix.

$$T_0^2 = \begin{bmatrix} -C_1 & -S_1 & 0 & -q_2S_1 \\ -S_1 & C_1 & 0 & q_2C_1 \\ 0 & 0 & -1 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



Find the inverse kinematics for this two axis robot. Since no tool at the end , tool configuration vector is only 3x1.

Find q_1 (θ_1)

Find q_2 (d_2)