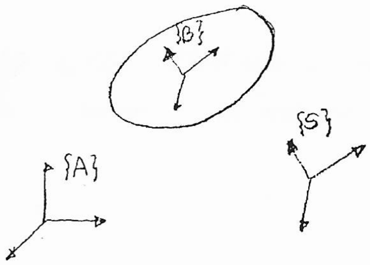
$-\begin{pmatrix}-1 & 0 & 0\\ 0 & 0 & -1\\ 0 & -1 & 0\end{pmatrix}\begin{pmatrix}0\\0\\3\end{pmatrix}$

2015 MMC Final Exam(Closed Book, No Question)

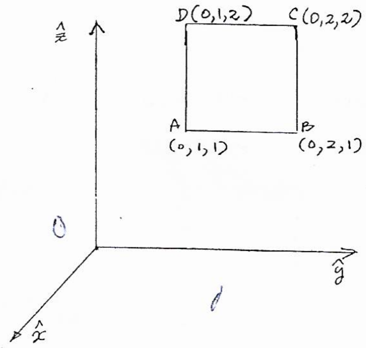
1. For the right figure,

$${}^{A}_{B}T = \begin{bmatrix} 0 & 0 & -1 & 1 \\ -0.5 & 0.866 & 0 & 2 \\ 0.866 & -0.5 & 0 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad {}^{S}_{B}T = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & -1 & 0 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Find ${}^{A}_{S}T$ (10 pts)



2. 1) When plate ABCD is rotated about y-axes by 60° and then, rotated about x-axes by 30°(Fixed angle rotation), descrbe the coordinates of the points A, C (10 pts)



2) When plate ABCD is rotated by 45° about $\overrightarrow{K} = [1,2,2]^T$, Answer the corresponding coordinates of B, D (10 pts)

$$R_K(\theta) = \begin{bmatrix} k_x k_x v\theta + c\theta & k_x k_y v\theta - k_z s\theta & k_x k_z v\theta + k_y s\theta \\ k_x k_y v\theta + k_z s\theta & k_y k_y v\theta + c\theta & k_y k_z v\theta - k_x s\theta \\ k_x k_z v\theta - k_y s\theta & k_y k_z v\theta + k_x s\theta & k_z k_z v\theta + c\theta \end{bmatrix}$$

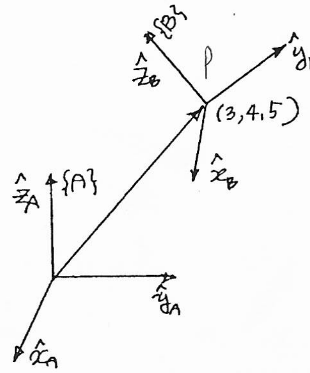
Where $c\theta = \cos\theta$, $s\theta = \sin\theta$, $v\theta = 1 - \cos\theta$, and ${}^{A}\hat{K} = [k_x \; k_y \; k_z]^T$.

45° 45 45 1 2 2

3. For {A} -> {B}, Find transformation matrix(${}^{A}_{B}T$).

where ${}^{A}(\widehat{x_B}) = [\frac{1}{\sqrt{2}} \; 0 \; -\frac{1}{\sqrt{2}}]^T$, ${}^{A}(\widehat{z_B}) = [\frac{1}{2} \; \frac{1}{\sqrt{2}} \; \frac{1}{2}]^T$.

(10pts)



4. 1) For the following Puma 560 Manipulator, Assign the required coordinate frames, and fill out the corresponding DH parameter table up to wrist center point, (15pts)

	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	0	θ_1
2	-90	0	0	θ_2
3	0	a_2	d_3	θ_3
4	-90°	a_3	d_4	θ_4

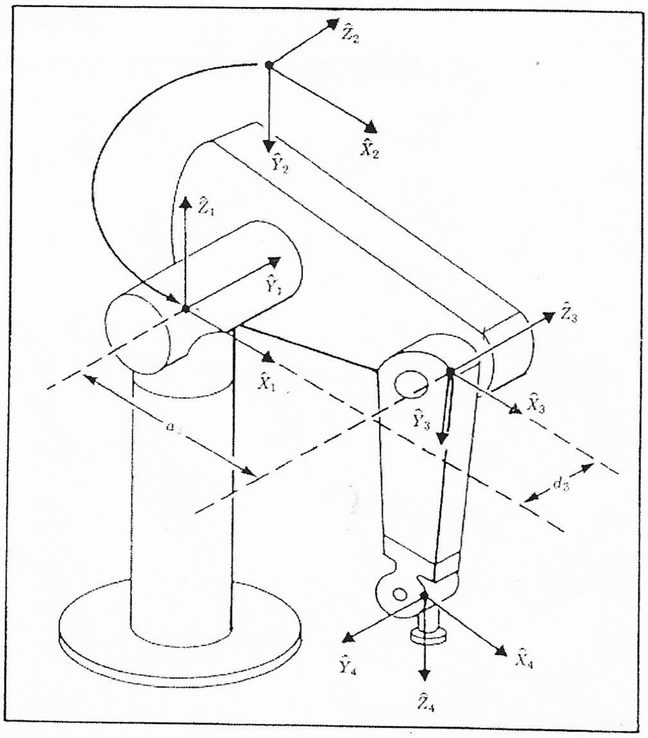


FIGURE 3.18 Some kinematic parameters and frame assignments for the PUMA 560 manipulator.

W

2) When $\theta_1 = 0°$, $\theta_2 = -30°$, $\theta_3 = 30°$, $a_2 = 1000$, $d_3 = 200$ Find the position of 3rd coordinate origin point with respect to the {0}-coordinate frame (15 pts)

3) When $\theta_1 = 0°$, $\theta_2 = 30°$, $\theta_3 = 30°$, $a_2 = 1000$, $d_3 = 200$, $a_3 = 1000$, $d_4 = 200$ Find the second column(6 by 1 vector) of the Jacobian(6 by 3 matrix) about the wrist center point with respect to the {0}-coordinate frame.(10pts)

$$ {}^{i-1}_{i}T = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1} d_i \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1} d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

4) When $\theta_1 = 0°$, $\theta_2 = 30°$, $\theta_3 = 30°$, $\dot{\theta}_1 = \dot{\theta}_2 = \dot{\theta}_3 = 2\,rad/\text{sec}.$ $a_2 = 1000$, $d_3 = 200$, $a_3 = 1000$, $d_4 = 200$ Find the linear velocities of the origin of the 3rd coordinate frame with respect to the {3}-coordinate frame.(15pts). Find the linear velocities of the origin of the 3rd coordinate frame {0}-coordinate frame(5 pts).

$$ {}^{i+1}\omega_{i+1} = {}^{i+1}_{i}R\,{}^{i}\omega_i + \dot{\theta}_{i+1}\,{}^{i+1}\hat{Z}_{i+1}, \qquad {}^{i+1}v_{i+1} = {}^{i+1}_{i}R({}^{i}v_i + {}^{i}\omega_i \times {}^{i}P_{i+1}) $$

5. $\theta(0) = 30°$ $\theta(t_f) = 90°$ $t_f = 1\text{sec}$ (10pts)
$\dot{\theta}(0) = 0$ $\dot{\theta}(t_f) = 0$

1) Do trajectory planning with a cubic polynomial for this joint control

u

6. Robot Dynamic Equation is given as $\tau = M(\theta)\ddot{\theta} + V(\theta, \dot{\theta}) + G(\theta)$
For the desired joint trajectory($\theta_d(t)$), the desired cartesian trajectory($x_d(t)$)
1) draw the Block diagram for Independent Joint PID control (5pts)
2) draw the Block diagram of Computed torque control (5pts)
3) For Cartesian based control, Find equivalent model M_x, V_x, G_x (5pts)
4) draw the Block diagram of Cartesian based Jacobian Transpose control(5pts)

2