

Solution

(Q1 -

(a)  $A_1 =$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(4)

$A_2 =$

(4)

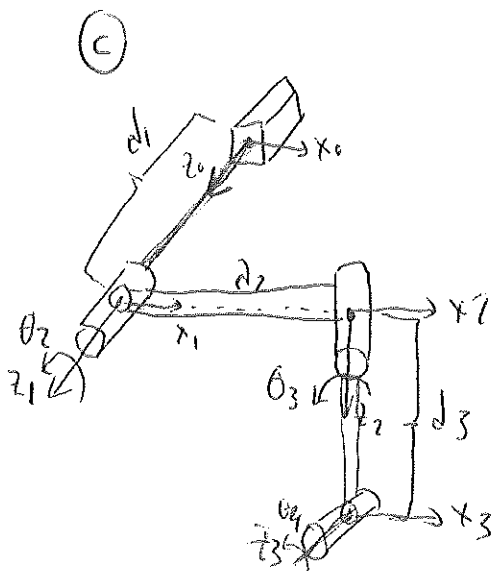
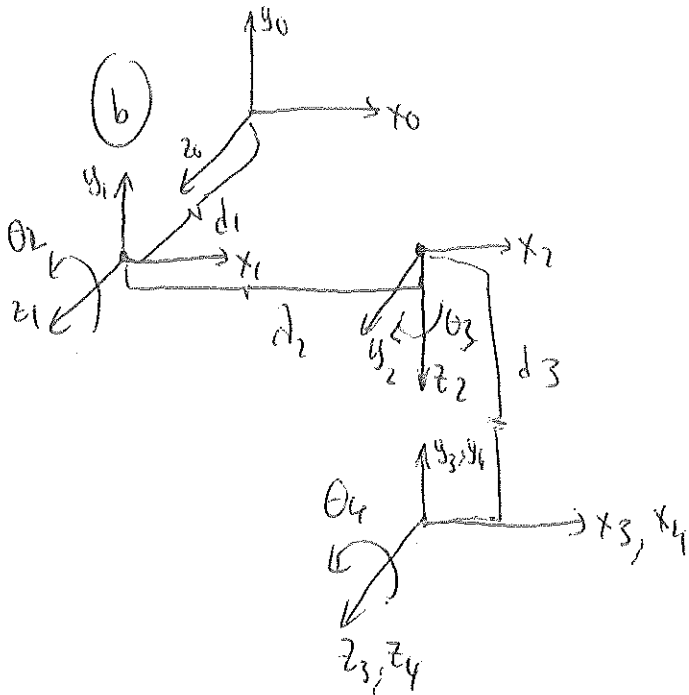
$$\begin{bmatrix} \cos \theta_2 & 0 & \sin \theta_2 & a_2 \cos \theta_2 \\ \sin \theta_2 & 0 & -\cos \theta_2 & a_2 \sin \theta_2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} \cos \theta_3 & 0 & -\sin \theta_3 & 0 \\ \sin \theta_3 & 0 & \cos \theta_3 & 0 \\ 0 & -1 & 0 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(4)


$$A_4 = \begin{bmatrix} \cos \theta_4 & -\sin \theta_4 & 0 & 0 \\ \sin \theta_4 & \cos \theta_4 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(3)



Q2)

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \text{Rot}(z, \phi) \text{Rot}(y, \theta) \text{Rot}(x, \psi)$$

 = 
$$\begin{bmatrix} \cos \phi \cos \theta & \cos \phi \sin \theta \sin \psi - \sin \phi \cos \psi & \cos \phi \sin \theta \cos \psi + \sin \phi \sin \psi \\ \sin \phi \sin \theta & \sin \phi \sin \theta \sin \psi + \cos \phi \cos \psi & \sin \phi \sin \theta \cos \psi - \cos \phi \sin \psi \\ -\sin \theta & \cos \theta \sin \psi & \cos \theta \cos \psi \\ 0 & 0 & 0 \end{bmatrix}$$

entry (3,1) 7 point

$$-\sin \theta = 0 \begin{cases} \theta = 0^\circ \\ \text{or} \\ \theta = 180^\circ \end{cases}$$

$[\theta \text{ can be } 0^\circ \text{ or } 180^\circ]$

entry (1,1) 7 point

$$\cos \phi \cos \theta = -1 \begin{cases} \text{if } \theta = 0 \Rightarrow \cos \phi = -1 & \phi = 180^\circ \\ \text{if } \theta = 180^\circ \Rightarrow \cos \phi = 1 & \phi = 0^\circ \end{cases}$$

entry (3,3) 6 point

$$\cos \theta \cos \psi = -1 \begin{cases} \text{if } \theta = 0 \Rightarrow \cos \psi = -1 & \psi = 180^\circ \\ \text{if } \theta = 180^\circ \Rightarrow \cos \psi = 1 & \psi = 0^\circ \end{cases}$$

solution 1  $\rightarrow \theta = 0^\circ, \phi = 180^\circ, \psi = 180^\circ$

solution 2  $\rightarrow \theta = 180^\circ, \phi = 0^\circ, \psi = 0^\circ$

0 point

Q3

5 point

$$\Delta = \begin{bmatrix} 0 & -\delta_z & \delta_y & dx \\ \delta_z & 0 & -\delta_x & dy \\ -\delta_y & \delta_x & 0 & dz \\ 0 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & -0.1 & 0 & 0 \\ 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & -0.1 & 0 & 0 \\ 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$dA = \Delta A = \begin{bmatrix} 0 & -0.1 & 0 & 0 \\ 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} -1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & -0.1 & 0 & 0 \\ 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

5 point