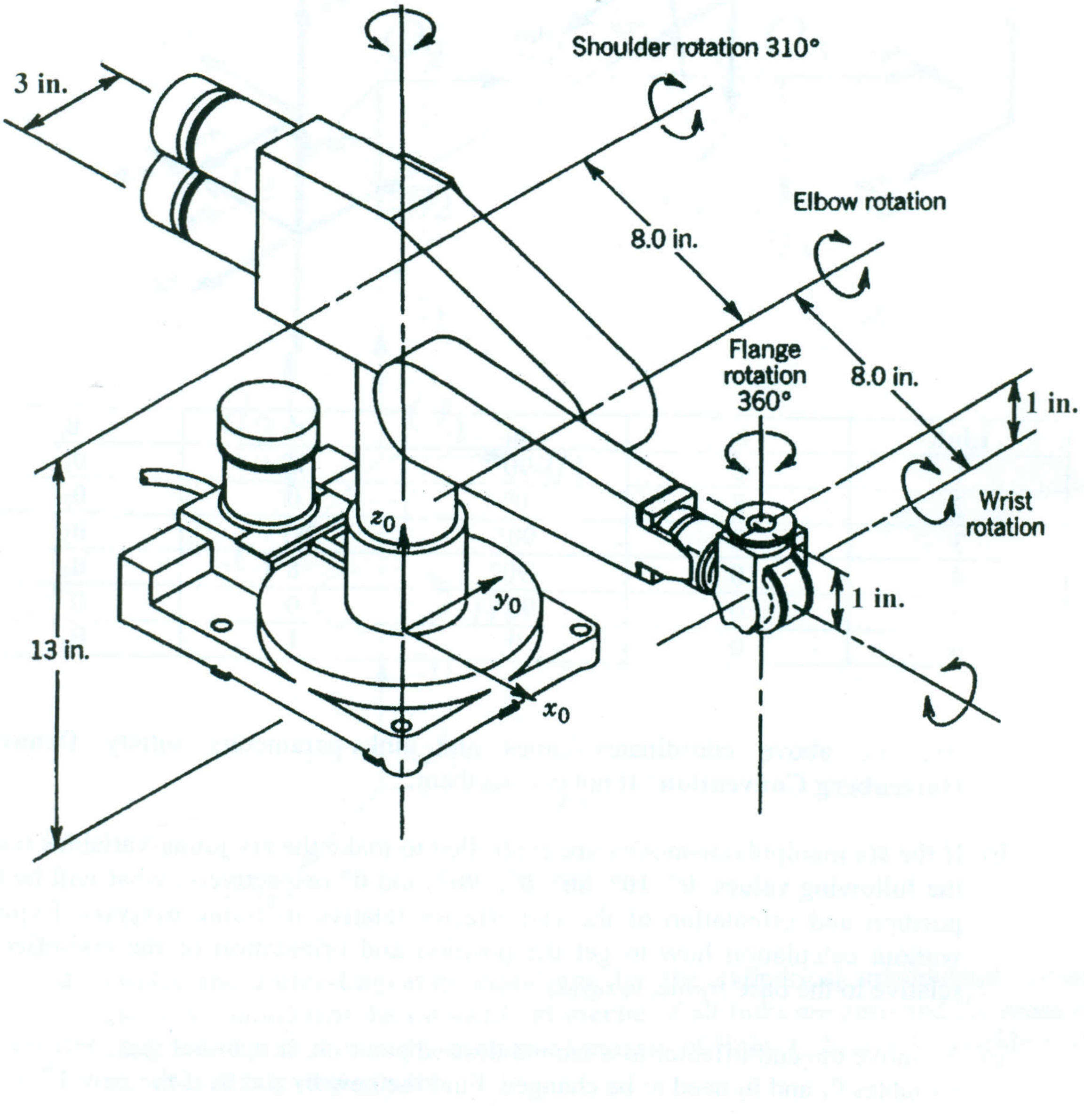
Mansoura University	**Robotics**
Faculty of Engineering	**Final Exam Sp. 2010**
Prod. Eng. & Mech. Design Dept.	**Time: 3 Hours**

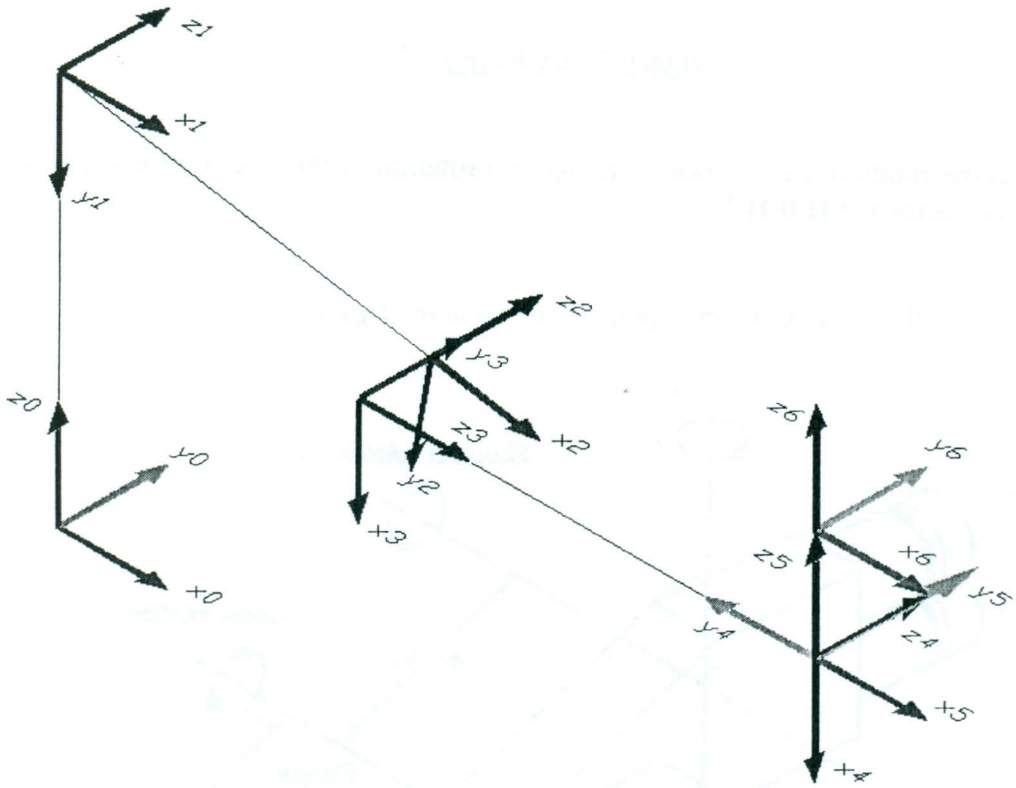
(Open Notes Exam)

1. Find the rotation matrix corresponding to a rotation of **90°** about an axis parallel to the vector $\mathbf{v} = [1\ 0\ 1]^T$.

2. Consider the PUMA 260 manipulator shown in the figure.



To derive the forward kinematic equations, the following coordinates frames and links parameters are suggested.



Link	a_i	α_i	d_i	θ_i
1	0	-90°	13	θ_1^*
2	8	0°	0	θ_2^*
3	0	90°	-3	θ_3^*
4	0	-90°	8	θ_4^*
5	0	90°	0	θ_5^*
6	0	0	1	θ_6^*

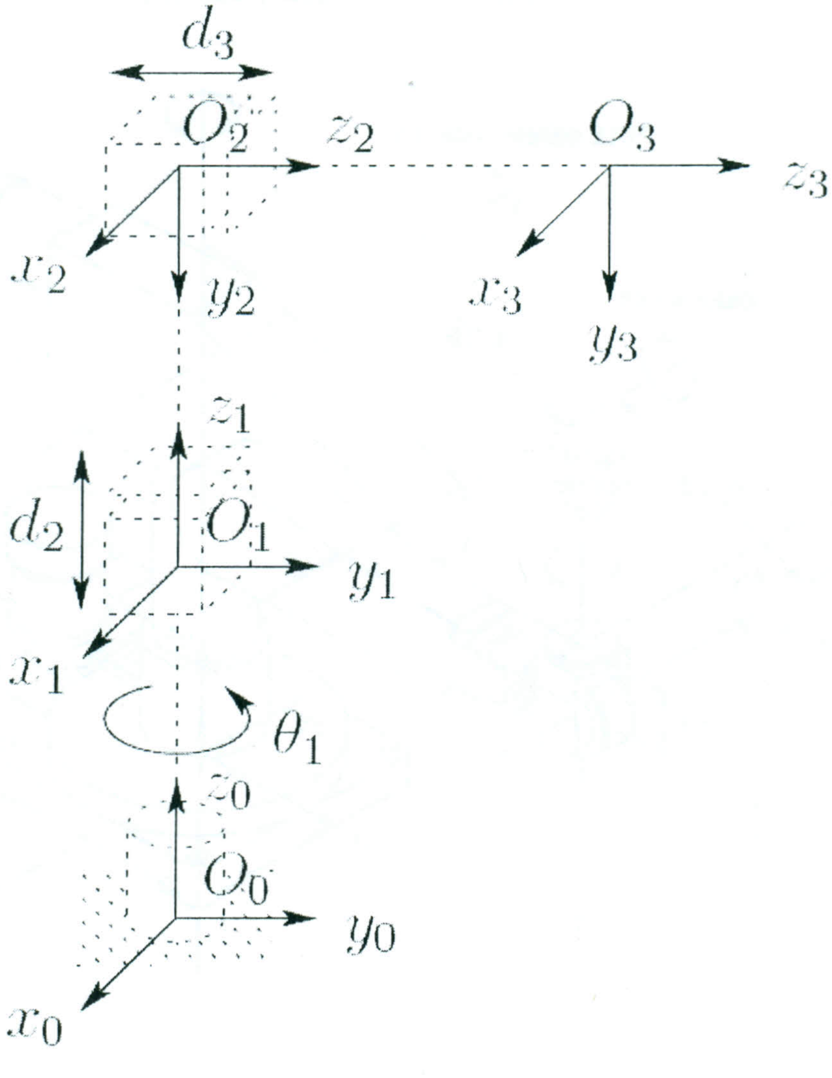
a) Are the above coordinates-frames and links-parameters satisfy **Denavit-Hartenberg Convention**? If not correct them.

b) If the six manipulator-motors are controlled to make the six joints-variables reach the following values: **0°**, **10°**, **80°**, **0°**, **-90°**, and **0°** respectively, what will be the position and orientation of the end-effector relative to frame $\mathbf{o_3x_3y_3z_3}$. Explain without calculation how to get the position and orientation of the end-effector relative to the base frame, $\mathbf{o_0x_0y_0z_0}$.

c) To move the end-effector to a second desired position, it is found that; only joints-variables θ_2 and θ_3 need to be changed. Find the new $\boldsymbol{\theta_2}$ and $\boldsymbol{\theta_3}$ if the new $\mathbf{T^0_3}$ is:

$$\begin{pmatrix} 0.259 & 0 & 0.966 & 6.928 \\ 0 & 1 & 0 & -3 \\ -0.966 & 0 & 0.259 & 9 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

3. Find the **6 × 3 Jacobian** for the three links of the cylindrical manipulator shown below. Find the **singular configurations** of this arm.



4. Derive the **Euler-Lagrange equations** for the cylindrical manipulator shown above assuming that the **moments of inertia** of all links are **zero** and the **mass** of each link equals **1**. Let the **centers of masses** of links **1**, **2**, and **3** coincide with **O_1**, **O_2**, and **O_3** respectively.