



COLLEGE OF ENGINEERING & TECHNOLOGY

Department : Electrical & Computer Control Engineering
Lecturer : Prof. Ahmed F. Amer
Course : Robotics Engineering
Course Code : EE514
Date : 22 / 1 / 2015

Marks : 40
Time : 2 hours

Answer The Following Questions:

1- a) Find the rotation matrix representing a roll of $\pi/4$ followed by a yaw of $\pi/2$ followed by a pitch of $\pi/2$. The rotations are taken relative to mobile frames. Sketch the frames. A.15 ,A.31

b) Find the homogeneous transformation matrix that represents the following translations and rotations relative to the current frames: A.15 ,A.31

- Rotation about y-axis by an angle of 45° .
- Translation along y-axis by 3-units.
- Translation along x-axis by 5-units.
- Rotation about x-axis by an angle of 90° .

2- a) Suppose that three coordinate frames $O_1 - X_1Y_1Z_1$, $O_2 - X_2Y_2Z_2$, $O_3 - X_3Y_3Z_3$ are given, and suppose: A.4

$$R_1^2 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1/2 & -\sqrt{3}/2 \\ 0 & \sqrt{3}/2 & 1/2 \end{bmatrix} ; \quad R_1^3 = \begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

Find the matrix R_2^3

b) A series of rotations and translations from frame $Q_0 - x_0y_0z_0$ to a new frame $Q_1 - x_1y_1z_1$ given by: A.4

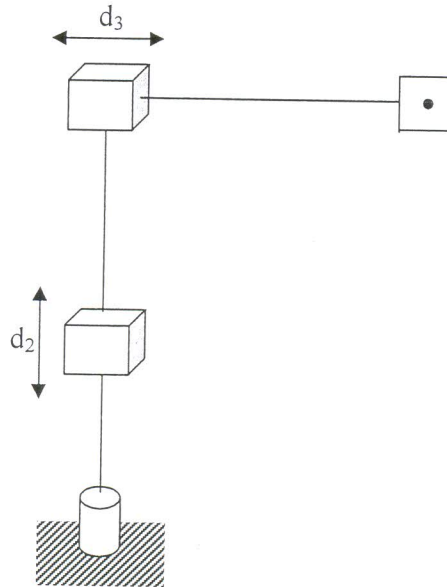
- Rotation about $x_0 - axis$ by an angle of ψ .
- Translation vector from origin Q_0 to origin Q_1 given by:

$$d_o^1 = d_x \cdot \bar{x} + d_y \cdot \bar{y}_o + d_z \cdot \bar{z}_o$$

- Rotation about $z_0 - axis$ by an angle of ψ .

Members of course Examination Committee:	Signature:	Date:
Lecturer: Prof. Ahmed Fouad M. Amer	<i>Ahmed F. Amer</i>	6/1/2015
Course Coordinator : Dr. Ahmed Elshenawy	<i>AKH</i>	18/1/2015
Head of Department: Prof. Hamdy Ashour	<i>Hamdy</i>	18/1/2015

3- Consider the cylindrical robot manipulator of figure 1. Derive the forward kinematic equations using the Denavit-Hartenberg convention. B.1 B.3



4- For the three-link planar manipulator robot, carry out the following steps:

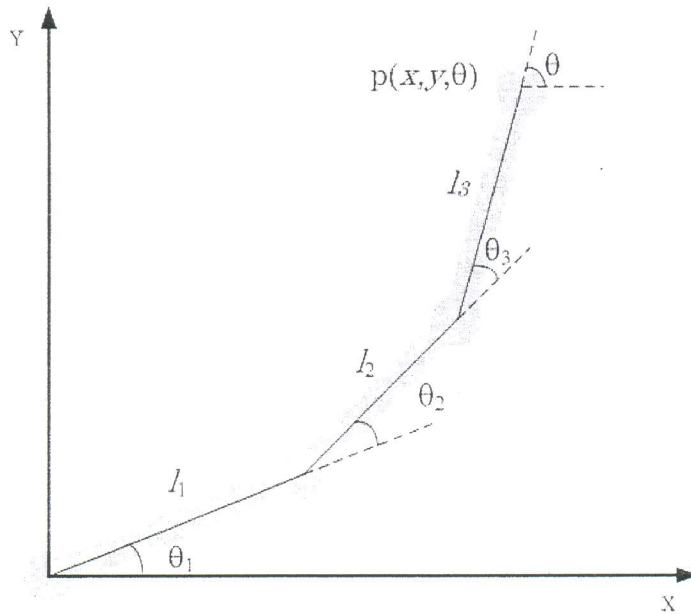
- Assign coordinate frames for the different links.
- Allocate link parameters.
- Find the forward kinematics transform.
- Find the inverse kinematics transform (that is, find the robot joint variables θ_1 , θ_2 , and θ_3 given the operational space vector variable χ), where:

$$\chi = \begin{bmatrix} P_x \\ P_y \\ \phi \end{bmatrix} = \begin{bmatrix} 2.8 \\ 3 \\ 75^\circ \end{bmatrix}$$

where ϕ is the sum of the revolute joint variables θ_1 , θ_2 , and θ_3 . The link lengths are: $l_1 = l_2 = l_3 = 1.5$ meter.

A1 B.1 A.4

Members of course Examination Committee:	Signature:	Date:
Lecturer: Prof. Ahmed Fouad M. Amer	<i>Ahmed F. Amer</i>	16/11/2015
Course Coordinator : Dr. Ahmed Elshenawy	<i>[Signature]</i>	18/11/2015
Head of Department: Prof. Hamdy Ashour	<i>Hamdy</i>	18/11/2015



Members of course Examination Committee:	Signature:	Date:
Lecturer: Prof. Ahmed Fouad M. Amer	<i>Ahmed F. Amer</i>	16/11/2015
Course Coordinator : Dr. Ahmed Elshenawy	<i>[Signature]</i>	18/11/2016
Head of Department: Prof. Hamdy Ashour	<i>Hamdy</i>	18/11/2016