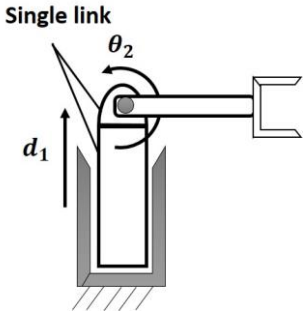
BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
HYDERABAD CAMPUS
First Semester (2022-23)
BITS F441: Robotics
Mid Semester Test **14th November 2022**
Time: 2.30 PM – 4.00 PM **Closed Book** **Max. Marks: 50**

Q1. For the manipulator shown in figure below, draw an equivalent line diagram (1.5 M), number the links (0.5 M), number the joints (0.5 M) and identify the type of joints (0.5 M). What is the degree of freedom of the manipulator (0.5 M)? Assign frames to this robotic arm (5 M) and hence determine the link joint parameters for each link (2+1.5 = 3.5 M). **12 M**



Q2. Link joint parameter table for a given manipulator arm, is given below. Determine the individual link transformation matrices $[0T_1]$ and $[1T_2]$ and overall arm transformation matrix $[0T_2]$ (3+3+2 = 8 M). Using the four operations for the four link joint parameters get each link transformation matrix. Don't use direct formula. If the joint space vector is given below, determine the Tool matrix is $[T_E]$ (2 M). What are the types of joints used (1 M) and what is the degree of freedom (1 M)? Give reasons. **12 M**

Link	a_i	α_i	θ_i	d_i
1	0	-90	θ_1	0
2	0	0	0	d_2

$$[q] = \begin{bmatrix} 40^0 \\ 0.2\ m \end{bmatrix}$$

Q3. The link joint parameter table is for a manipulator arm is given below. Determine individual link transformation matrices $[0T_1]$, $[1T_2]$ and $[2T_3]$ (6 M) using the four operations for the four link joint parameters. Don't use direct formula. Also determine $[0T_2]$ (2 M). Hence, determine the manipulator arm transformation matrix, $[0T_3]$ (2 M). Write all possible kinematic equations (2 M). Hence determine the joint space vector for the given Cartesian space vector (6M). How many joints are used (0.5 M)? What type of joints used (1 M) and what is the degree of freedom of the arm (0.5 M)? **20 M**

Link	a_i	α_i	d_i	θ_i
1	0	90	0	θ_1
2	$0.2\ m$	0	0	θ_2
3	$0.15\ m$	0	0	θ_3

$$T_E = \begin{bmatrix} 0.406 & -0.579 & 0.707 & 0.169 \\ 0.406 & -0.579 & -0.707 & 0.169 \\ 0.819 & 0.574 & 0 & 0.251 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Q4. A robotic RPY wrist is given first rolling motion of 30^0, followed by pitching motion of 45^0 and finally yawing motion of 60^0. Draw a neat diagram showing the three axes of rolling, pitching and yawing (1.5 M). Assign the axes X, Y, Z to these three axes of rolling, pitching and yawing. Hence determine the overall rotation matrix (2 M). What are coordinates of a point $P = [2 \quad 2 \quad 4]^T$ after these three motions (1 M)? What are $[n \quad o \quad a]$ vectors (0.5 M)? What are their directions (1 M)? Show them in the diagram. **6 M**