Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

DEPARTMENT OF MECHATRONICS

I SEMESTER M.TECH. INDUSTRIAL AUTOMATION AND ROBOTICS

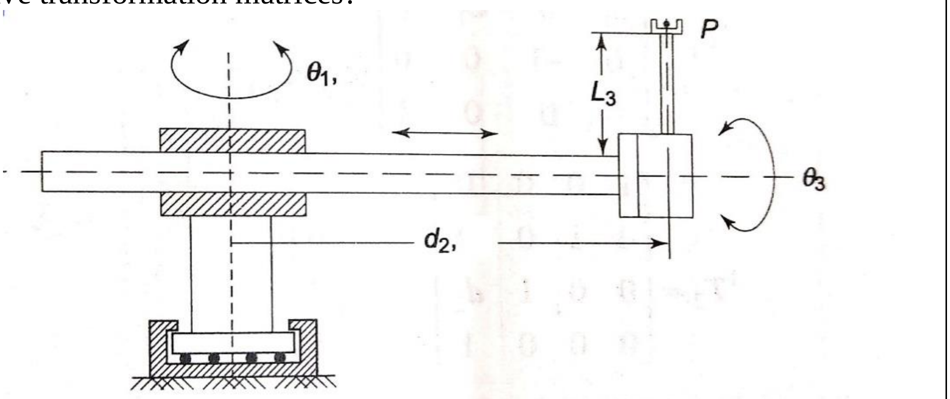
END SEMESTER EXAMINATION, NOVEMBER 2023

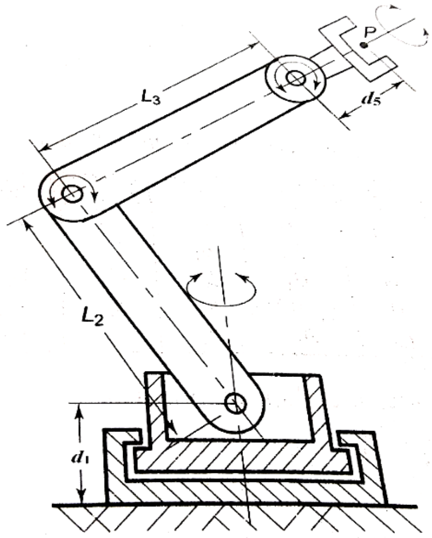
SUBJECT: ROBOT KINEMATICS AND DYNAMICS [MTE 5113]

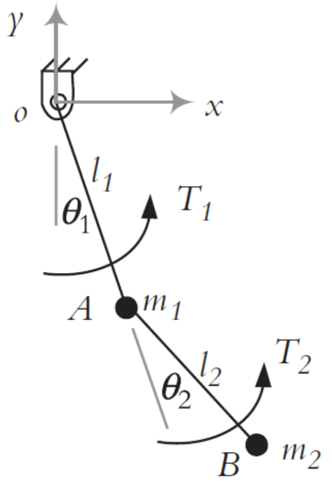
Time: 3 hours **Date: 05/12/2023** **Max. Marks: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed and justified.

Q. No	PROBLEM STATEMENT	M	CO	PO	LO	BL
1A.	Formulate the relation to invert homogeneous transform from frame {1} to frame {2} with a suitable diagram.	**5**	**1**	**1,3**	**1,2**	**5**
1B.	Apply DH convention for evaluating the forward kinematics of the RPR manipulator shown in Fig.Q1B Identify the Frame assignment, DH tables and all respective transformation matrices?  **Fig. Q1B**	**5**	**2**	**1,3**	**1,2**	**5**
2A.	Determine the joint variables (θ_1, θ_2 and d_3) for 4-DOF SCARA manipulator. When: ${}^0T_4 = \begin{bmatrix} C_{124} & S_{124} & 0 & L_2C_{12} + L_{11}C_1 \\ S_{124} & -C_{124} & 0 & L_2S_{12} + L_{11}S_1 \\ 0 & 0 & -1 & L_{12} + d_3 - L_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ $T_E = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ 0 & 0 & 0 & 1 \end{bmatrix}$ Where, $\text{Cos}(\theta_1) = C_1$ $\text{Sin}(\theta_1) = S_1$ $\text{Cos}(\theta_1 + \theta_2) = C_{12}$ $\text{Sin}(\theta_1 + \theta_2) = S_{12}$ $\text{Cos}(\theta_2) = C_2$ $\text{Sin}(\theta_2) = S_2$ $\text{Cos}(\theta_1 + \theta_2 - \theta_4) = C_{124}$ $\text{Sin}(\theta_1 + \theta_2 - \theta_4) = S_{124}$	**5**	**2**	**1,3**	**1,2**	**5**

2B.	Construct the frame assignment and DH table of the 5-DOF industrial manipulator shown in Fig. Q2B using D-H method.  **Fig. Q2B**	**5**	**2**	**1,3**	**1,2**	**3**
3A.	Determine the new location of the hand after the differential motion, if hand frame of 2RP2R manipulator its numerical Jacobian (J) for this instance, and a set of differential motions are given. $T_6 = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 0 & -1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad J = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} d\theta_1 \\ d\theta_2 \\ ds_1 \\ d\theta_4 \\ d\theta_5 \end{bmatrix} = \begin{bmatrix} 0.1 \\ -0.1 \\ 0.05 \\ 0.1 \\ 0 \end{bmatrix}$	**5**	**3**	**1,3**	**1,2**	**5**
3B.	Determine the jacobian matrix for the 3-DOF robotic arm. The transformation matrix is given below. ${}^0T_1 = \begin{bmatrix} C_1 & 0 & -S_1 & 0 \\ S_1 & 0 & C_1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^1T_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^2T_3 = \begin{bmatrix} C_3 & 0 & S_3 & L_3C_3 \\ S_3 & 0 & -C_3 & L_3S_3 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ Where, $\cos(\theta_1) = C_1$ $\sin(\theta_1) = S_1$ $\cos(\theta_3) = C_3$ $\sin(\theta_3) = S_3$	**5**	**3**	**1,3**	**1,2**	**5**

4A.	Develop equation of motion of 2-degree of freedom manipulator shown in Fig. Q4A using Euler-Lagrangian method. Estimate the total kinetic energy of the manipulator.  **Fig. Q4A**	**5**	**3**	**1,3**	**1,2**	**5**
4B.	Develop equation of motion of 2-DOF manipulator, link 1 and link 2 are making joint angle from horizontal axis using Euler-Lagrangian method. The center of mass for each link is at the center. The mass of the link 1 and link 2 are m_1 and m_2, length of link 1 and link 2 are L_1 and L_2, joint angles are θ_1 and θ_2 moment of inertia are I_1 and I_2 respectively. Determine the total potential energy of the manipulator.	**5**	**3**	**1,3**	**1,2**	**5**
5A.	Using a fifth-order polynomial, determine the joint angle at 1, 2, 3, and 4 seconds, if the first joint of a 6-axis robot go from initial angle of 30° to a final angle of 75° in 5 seconds. Assume the initial acceleration and final deceleration will be 5° /Sec^2.	**5**	**4**	**1,3**	**1,2**	**5**
5B.	Formulate the equations of third-order polynomial joint space trajectory planning.	**3**	**4**	**1,3**	**1,2**	**5**
5C.	Determine the new position of vector *P*, if vector *P* = 3i −2j + 5k is first rotated by 90° about y-axis, then by 90° about *x*-axis, then it is translated by −3i + 2j − 5k.	**2**	**1**	**1,3**	**1,2**	**5**