Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

V SEMESTER B.TECH. (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATION, NOV 2019

SUBJECT: MECHANICS OF ROBOTIC SYSTEM [MTE 3102]

(18/11/2019)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Data not provided may be suitably assumed

1A.	Explain linear hydraulic actuators? Mention any three features and applications of hydraulic actuators.	**05**	**CO1**
1B.	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 $-3i + 2j - 5k$.	**03**	**CO2**
1C.	Explain the procedure to invert a homogeneous transform from frame {1} to frame {2} with a suitable diagram.	**02**	**CO2**
2A.	Determine the frame assignment, D-H table and transformation matrix ${}^{0}\boldsymbol{T}_{3}$ of 3-DOF, RPP configuration arm shown in Fig.Q2A using D-H convention.	**05**	**CO3**

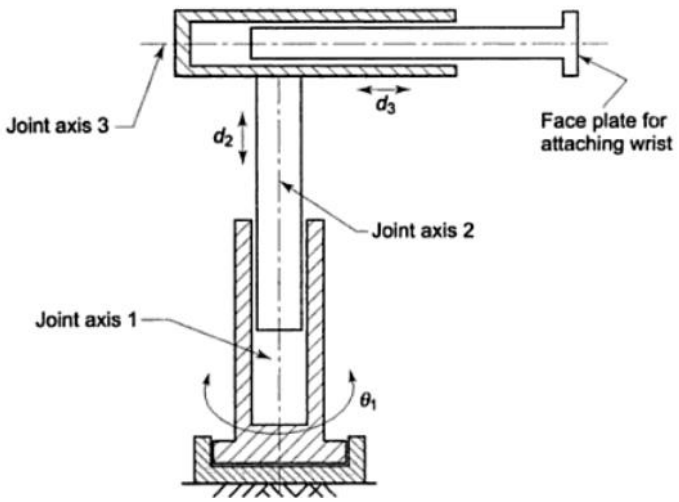

Fig. Q2A

2B. Determine the joint variables (θ_1, θ_2, d_3 and θ_4) for 4-DOF SCARA manipulator. When: **05 CO3**

$$ {}^0T_4 = \begin{bmatrix} C_{124} & S_{124} & 0 & L_2C_{12} + L_{11}C_1 \\ S_{124} & -C_{124} & 0 & L_2S_{12} + L_{11}S_1 \\ 0 & 0 & -1 & L_{12} + d_3 - L_4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_E = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

Where, $\text{Cos}(\theta_1) = C_1$ $\text{Sin}(\theta_1) = S_1$ $\text{Cos}(\theta_{1+}\ \theta_2) = C_{12}$ $\text{Sin}(\theta_{1+}\ \theta_2) = S_{12}$
$\text{Cos}(\theta_2) = C_2$ $\text{Sin}(\theta_2) = S_2$ $\text{Cos}(\theta_{1\ +}\ \theta_2 - \theta_4) = C_{124}$
$\text{Sin}\ (\theta_{1\ +}\ \theta_2 - \theta_4) = S_{124}$

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. **05 CO3**

$$ T_6 = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 0 & -1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad J = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} d\theta_1 \\ d\theta_2 \\ ds_1 \\ d\theta_4 \\ d\theta_5 \end{bmatrix} = \begin{bmatrix} 0.1 \\ -0.1 \\ 0.05 \\ 0.1 \\ 0 \end{bmatrix} $$

3B. Apply DH convention for evaluating the forward kinematics of the RPR manipulator shown in Fig.Q3B Identify the Frame assignment, DH tables and all respective transformation matrices? **04 CO3**

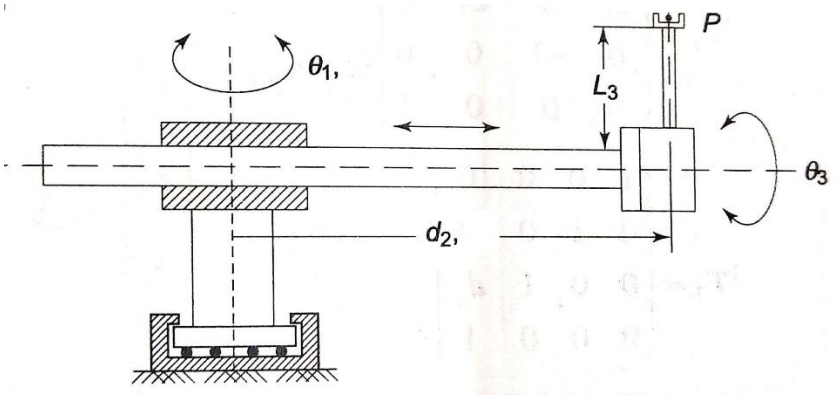

Fig. Q3B

3C. Recall the joint specification and work volume of the Cartesian arm configuration. **01 CO1**

4. Develop equations of motions of 2-degree of freedom manipulator shown in Fig. Q4 using Lagrangian formulation. Calculate: **CO4**

(i) The kinetic and potential energy of link 1 and 2. **06**

(ii) The torque of joint 2. **04**

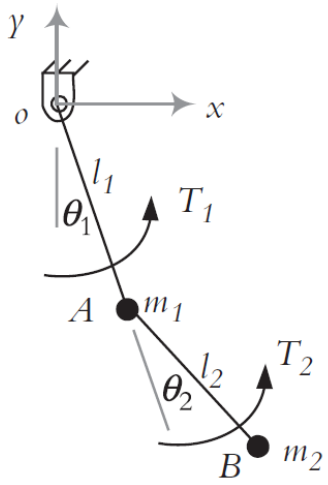

Fig. Q4

5A. Define Trajectory Planning? Explain the third-order polynomial trajectory planning. **04** **CO5**

5B. Using a fifth-order polynomial, calculate 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. **06** **CO5**