Ref.No.:Ex/ME(M1)/PE/B/T/424B/2022

B.E. MECHANICAL ENGINEERING FOURTH YEAR SECOND SEMESTER – 2022

Subject - Robotics

Time 4 hours **Full Marks 70**

Answer any five questions

Assume necessary data

1. (i) Answer any three questions. (3x2)

(a) "Modern day industrial robots are not *androids* to impersonate humans, rather *patterned after* human arm" – state the significance.

(b) What are major, minor and redundant axes of a robot?

(c) State the factors on which load carrying capacity of a robot depends.

(d) How a limit switch can be used as sensor of a robotic manipulator?

(ii) Deduce the following applying D-H algorithm:

$$T_i^{i-1} = \begin{bmatrix} \cos\theta_i & -\cos\alpha_i \sin\theta_i & \sin\alpha_i \sin\theta_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\alpha_i \cos\theta_i & -\sin\alpha_i \cos\theta_i & a_i \sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The terms have usual meanings. Draw necessary figure assigning (i)-th& (i-1)-th frames, link and joint parameters. 8

2. A 3-DOF robotic manipulator is expressed in terms of the joint-link parameters as shown in the Table Q2. Draw the line diagram of the robot. Find the overall transformation matrix for the following values of the joint parameters: $\theta_1 = 30^0$, $\theta_2 = 45^0$, $\theta_3 = 60^0$

(7+7)

Axes	a	α	d	θ
1	5	0	5	θ_1
2	15	90^0	10	θ_2
3	5	0	0	θ_3

Table Q2

[Turn over

3. A 4-DOF manipulator is shown in Fig.Q3. For the link and joint parameters shown on the figure determine the position and orientation of the point P on the tool with respect to the base coordinate frame. 14

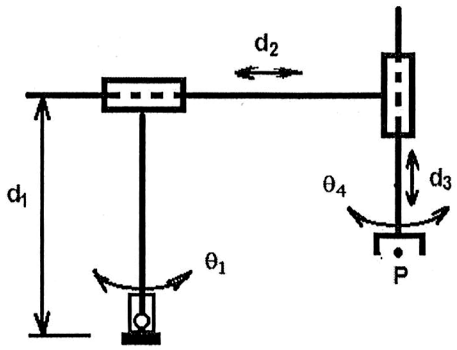

Fig. Q3

4. A robotic manipulator has the following forward kinematic equations:

$$T_P^{Base} = \begin{bmatrix} C_1C_{23} & -C_1S_{23} & S_1 & C_1(C_2+C_{23}) \\ C_1C_{23} & -S_1S_{23} & -C_1 & S_1(C_2+C_{23}) \\ S_{23} & C_{23} & 0 & S_2+S_{23} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

A point on the hand requires acquiring the position and orientation given by the following matrix:

$$[P] = \begin{bmatrix} 0.163 & -0.059 & 0.985 & 0.296 \\ 0.925 & -0.337 & -0.174 & 1.68 \\ 0.324 & 0.94 & 0 & 0.985 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Find out the joint parameters θ_1, θ_2 & θ_3. 14

5. For a cylindrical 3-DOF (RPP) robot the link-joint parameters are given in Table Q5. Find the Jacobian of the robot. 14

Axes	a	α	d	θ
1	0	0	0	θ_1
2	0	-90^0	d_2	0
3	0	0	d_3	0

Table Q5

6. Develop a fuzzy inference system for a robot, where force exerted at the hand and the velocity of the hand are the inputs and the percent power to the actuators is the output. It is desired that there should be at least three sets each for force, velocity and percent power. State also the method of defuzzification. 14

7. (a) For an RPR robot D-H parameters are given in Table Q7. Determine the values of the derivative of the transformation of the 3rd link relative to the base frame with respect to the second and first joint variables. Also find out U_{312}.

Axes	a	α	d	θ
1	0	90^0	0.5	θ_1
2	1	0	d_2	0
3	0.2	90^0	0	θ_3

Table Q7

(b) Following two cubic polynomials are used for designing a robot trajectory passing through a via-point: $\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3$ & $\theta(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3$

The initial, via-point and final positions are θ_1, θ_v and θ_2 respectively. It is required to satisfy velocity and acceleration smoothness at via-point. Times allotted for first and second polynomials are t_1 and $t_2$respectively. Determine the polynomial equations. (7+7)