U.S.N.										

B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

September / October 2023 Supplementary Examinations

Programme: B.E. **Semester: VI**
Branch: Mechanical Engineering **Duration: 3 hrs.**
Course Code: 20ME6DEROB **Max Marks: 100**
Course: Fundamentals of Robotics

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

UNIT - I

1 a) A vector ${}^{A}P$ is rotated about $\hat{X}_A$by θ degrees and is subsequently rotated about $\hat{Y}_A$ by ϕ degrees. Give the rotation matrix that accomplishes these rotations in the given order. **10**

b) Discuss five different applications of robots(present and future). **10**

OR

2 For the SCARA manipulator shown in Fig. 2, assign link frames, give the DH parameters and find the transformation matrices ${}^{0}_{1}T, {}^{1}_{2}T, {}^{2}_{3}T, {}^{3}_{4}T \text{ and } {}^{0}_{4}T$. **20**

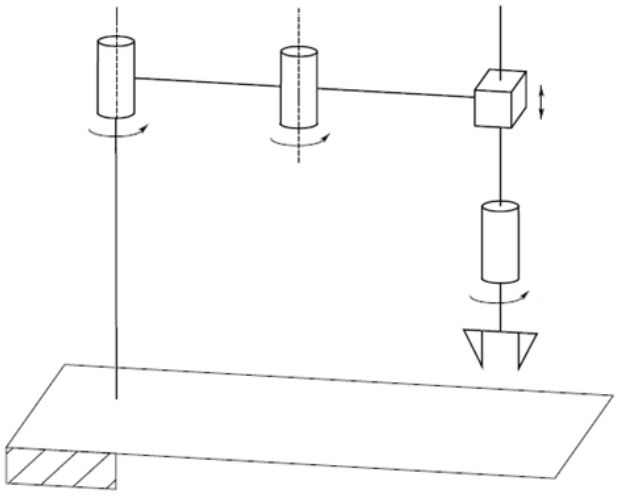


Fig. 2

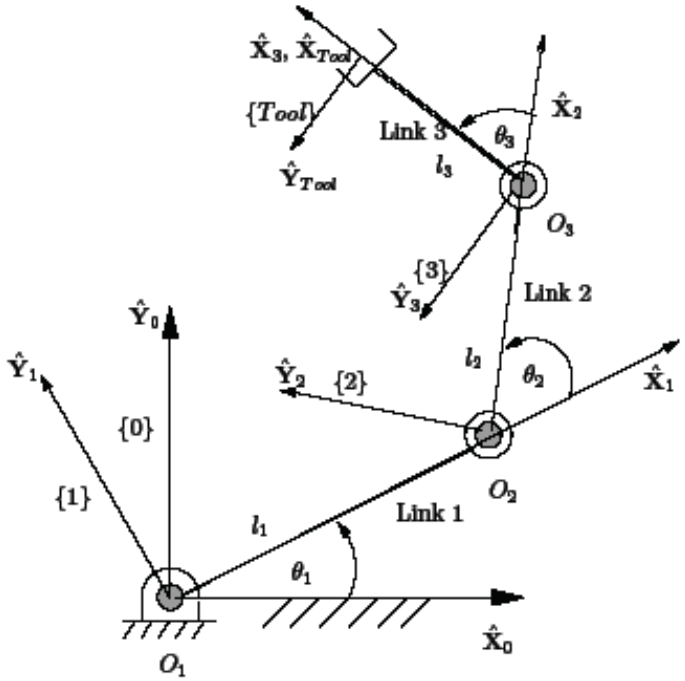
Hint:

$$ {}^{i-1}_{i}T = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1}d_i \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1}d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}. $$

UNIT - II

3 a) Perform the inverse kinematics for the Planar 3R manipulator using geometric approach. The position and orientation of the wrist frame (3) relative to the base frame (0) is given by the **10**

transformation matrix ${}^{0}_{3}T = \begin{pmatrix} c_{123} & -s_{123} & 0 & l_1c_1 + l_2c_{12} \\ s_{123} & c_{123} & 0 & l_1s_1 + l_2s_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$. If the desired position and orientation of the wrist frame is given by $\begin{pmatrix} c\phi & -s\phi & 0 & x \\ s\phi & c\phi & 0 & y \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$ find the joint angles.



b) Consider the 2R planar manipulator. if $L_1 = 2L_2$, the joint limits are $0 \leq \theta_1 \leq 180°$ and $-90 \leq \theta_2 \leq 180°$, sketch the approximate reachable workspace (an area) of the tip of link 2. **10**

OR

4 a) Derive the Jacobian that relates the joint velocities and linear velocities of the tip of a 2R planar manipulator. **10**

b) What is singularity? Using the result in 4a find the singularities of the 2R planar manipulator. **10**

UNIT - III

5 a) A single robot with a rotary joint is motionless at θ = 10 degrees. It is desired to move the joint in a smooth manner to θ = 90 degrees in 2 seconds. Find the coefficients of a cubic that accomplishes this motion and brings the manipulator to rest at the goal. Also sketch the position, **10**

velocity and acceleration of the joint as a function of time.

b) A single robot with a rotary joint is motionless at $\theta = 10$ degrees. It is desired to move the joint in a smooth manner to $\theta = 90$ degrees in 2 seconds. Find a trajectory using a linear function with parabolic blends that accomplishes this motion and brings the manipulator to rest at the goal. Also sketch the position, velocity and acceleration of the joint as a function of time. **10**

UNIT - IV

6 a) Consider a single link of a robot. The inertial load, I, varies between 4 and 5 kg-m^2. The rotor (motor) inertia is 0.01 kg-m^2, and the gear ratio is 10. The system possesses an unmodeled resonance due to an end-point stiffness of the link of 2400 N-m/radian. Design a partitioned controller such that the system is never underdamped and never excites resonances, but is as stiff as possible. **10**

b) Explain the architecture of PUMA 560 robot controller. **10**

UNIT - V

7 a) Compare hydraulic, pneumatic and electric actuating systems. **10**

b) Explain the important characteristics to be considered for selecting a sensor. **10**

****