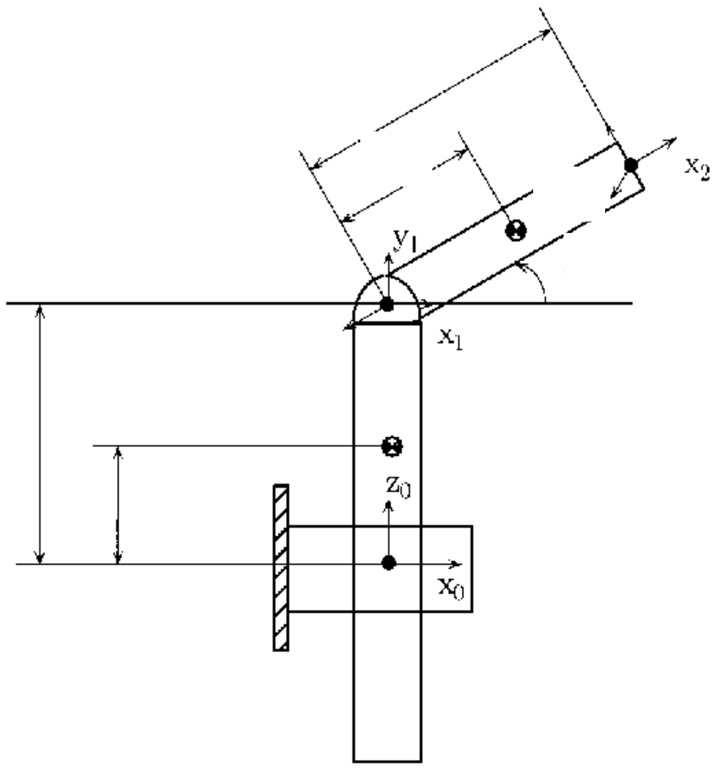
ME604: Introduction to Robotics

Spring 2025

Assignment 4

1. Consider the planar 2-link manipulator shown below.

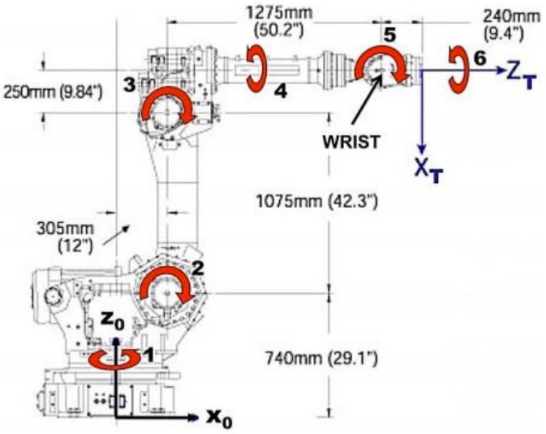


Derive the Jacobian relating the linear velocity of the end-effector (origin of x_2y_2) to joint rates – (i) by direct differentiation; (ii) using DH parameters. Determine the singular configurations of the robot, and comment on how the robot arm 'loses' degrees of freedom in those configuration.

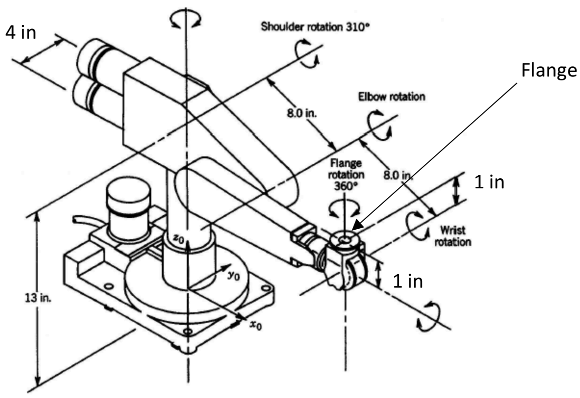
2. Given the Euler angle transformation $R = R_x(\psi)R_y(\theta)R_z(\phi)$. Derive the expression for ω such that $dR/dt = S(\omega)R$.

3. The figure below shows an industrial manipulator. At the **instant shown**, what is the Jacobian that relates the <u>linear velocity</u> of the end-effector to the joint angular velocities?

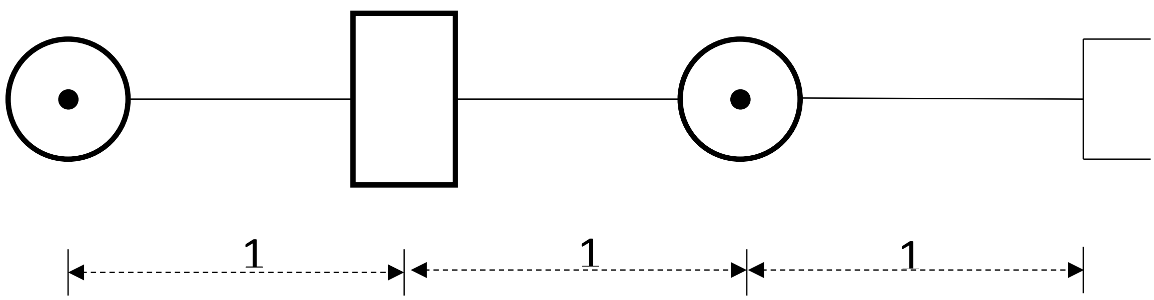
   Hint: Since we are interested in the Jacobian at current instant, you do **not** need to compute the Jacobian as a function of joint angles analytically.



4. At the instant shown, the rate of change of all joint angles, for the PUMA manipulator shown below, is 1 rad/s. Determine the angular velocity of the flange, and the linear velocity of the tip of a 6 in long screwdriver held at the flange such that the tip points upwards.

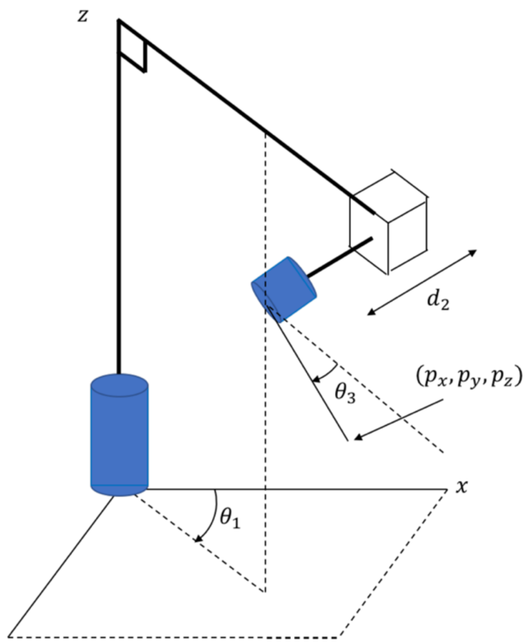


5. Consider the RRR manipulator shown below.



(a) Assign DH frames and find the DH parameters for this manipulator.
(b) Derive the forward kinematics, ${}^0_3T$, of this manipulator (frame $\{3\}$ being the end-effector frame)
(c) Derive the basic Jacobian, $J(q)$, for this manipulator.

6. Consider the manipulator shown below:



(a) Assign DH frames and find the DH parameters for this manipulator.
(b) Derive the basic Jacobian for this manipulator.
(c) Find ${}^1J_v$, the Jacobian matrix expressed in {1}.
(d) Identify and comment on singular configurations of the manipulator.

7. Consider the parallelogram-based single degree of freedom robot mechanism shown below. The mechanical structure is such that the opposing links of the manipulator remain parallel to each other at all times.
Write the co-ordinates of the end effector (x_e, y_e) as a function of link lengths and joint angle θ.
Differentiate the expressions obtained to write the 2 X 1 Jacobian for the manipulator. Can you use DH-parameter representation for this?