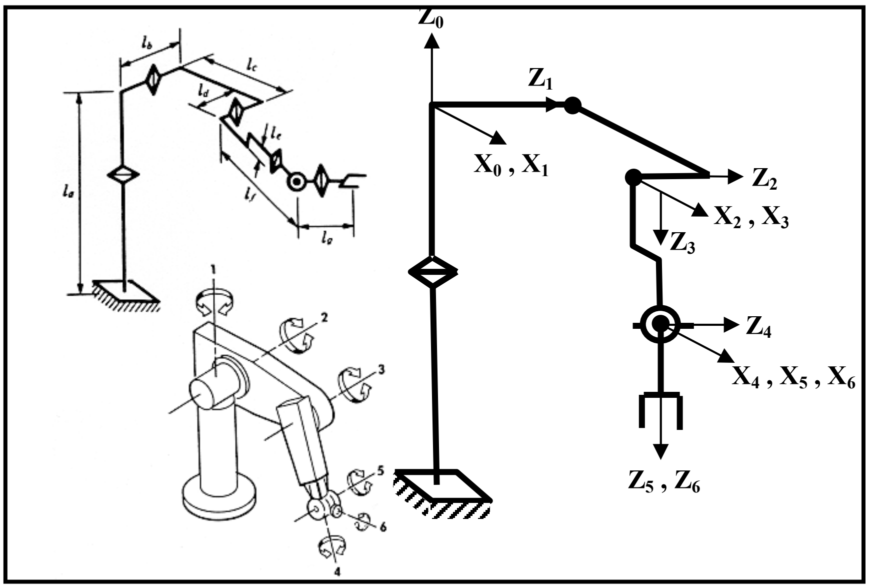
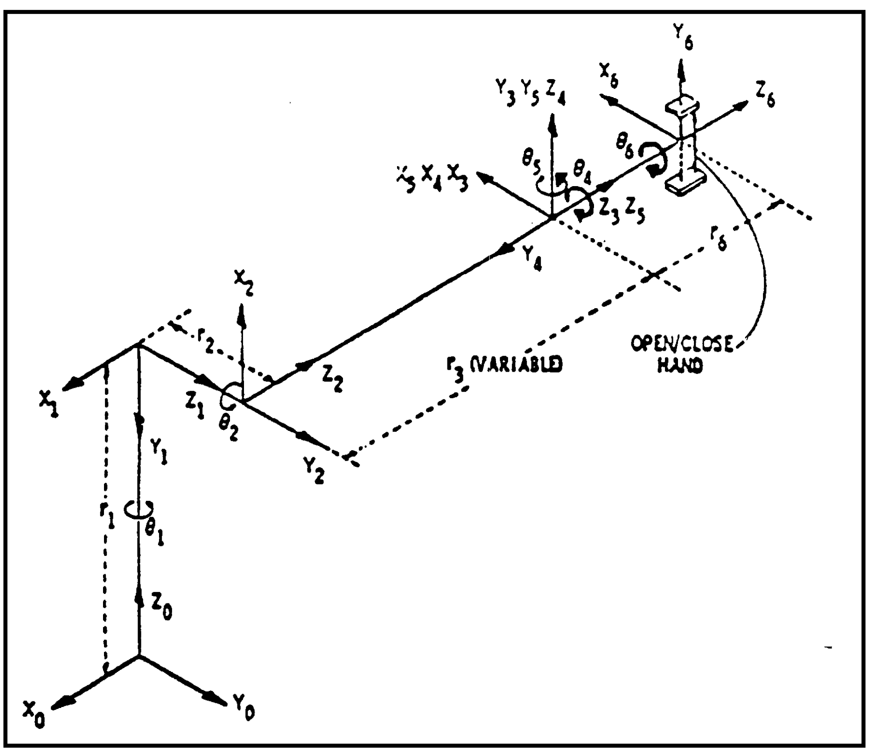
ME4524 – Robotics and Automation

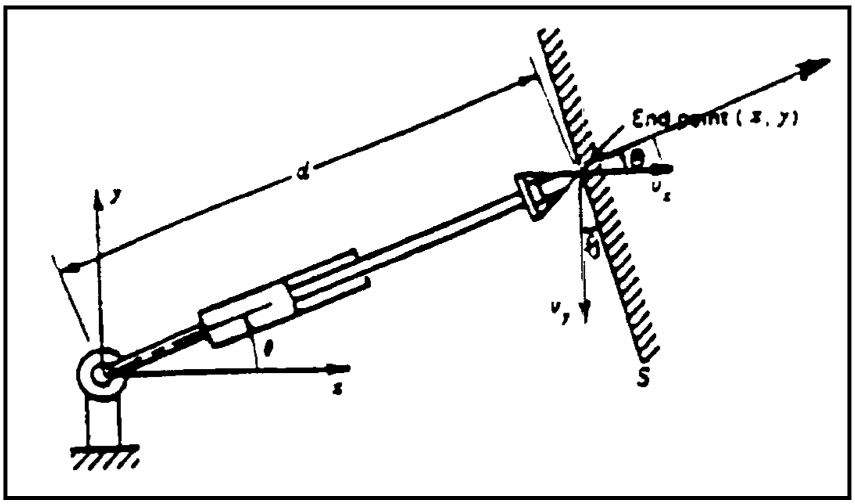
Exercise # 3

1. Obtain the Jacobian $J_0(q)$ for: **(i)** the PUMA 560 manipulator; and **(ii)** the Stanford manipulator shown in the Figure below. <u>NOTE:</u> For the Stanford manipulator, the math gets messy if we assume that r_6 has a non-zero length. Since the manipulator has a spherical wrist we can simplify things by assuming that r_6=0.

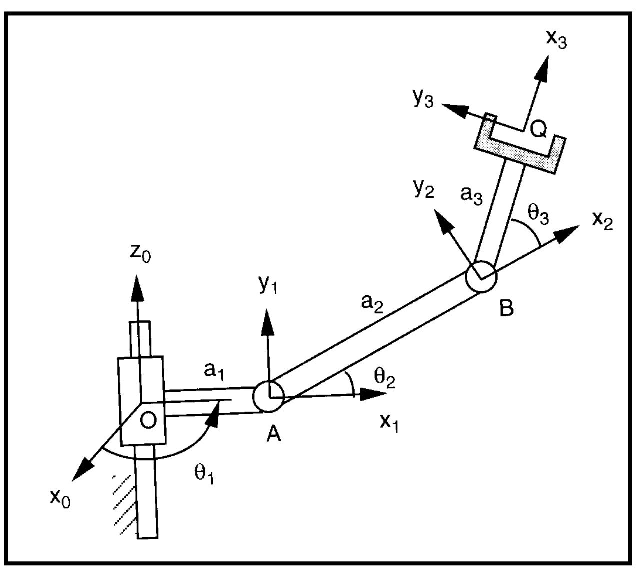




2. A planar manipulator consisting of a revolute and a prismatic joint is shown in the figure below.
   (a) Derive the Jocobian matirx $J_0\ (q)$ associated with the coordinate transformation from joint displacements θ and d to the end-point position x and y.
   (b) The end-effector is required to move along the flat surface **S** at a constant velocity (v_x, v_y). Compute the corresponding joint velocities and accelerations in terms of the joint displacements.



3. Find the joint angles needed to bring the end-effector of the manipulator shown in the figure below to a given position. Corresponding to a given position, how many number of possible arm configuartions exist?



4. A planar manipulator with three revolute joints is shown in the figure below. $a_1 = 50\sqrt{2} - 50$ cm, $a_2 = 25\sqrt{2}$ cm, $a_3 = 10$ cm.

   (a) Compute the end-point velocities $\dot{x}$, $\dot{y}$, and $\dot{\alpha}$, given that the joint angeles and angular velocities are $\theta_1 = 120$ deg., $\dot{\theta}_1 = 5$ deg/s, $\theta_2 = -120$ deg, $\dot{\theta}_2 = 120$ deg/sec, $\theta_3 = -90$ deg, and $\dot{\theta}_3 = 20$ deg/sec.

   (b) The end-point is required to move from point A(35, $50\sqrt{2} - 25$) to point B(35, $50\sqrt{2} - 75$) along the y-axis at a constant speed of 10 cm/s. Assuming that link 3 is kept parallel to the x-axis, compute the required angular velocities when the end-point is at A.

   (c) If no condition is imposed on the orientation of link 3 during the motion from A to B, determine the joint velocities at point A that minimizes the following squared norm:

   $$v^2 = \dot{\theta}_1^{\,2} + \dot{\theta}_2^{\,2} + \dot{\theta}_3^{\,2}$$

   Assume that link 3 is parallel to x-axis at A.

   (d) In the motion of part (b), does the manipulator Jacobian become singular? If so, determine the singular configuration and the direction along which the arm cannot move.