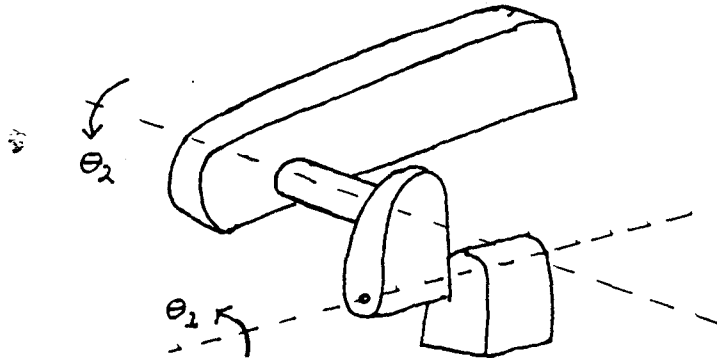


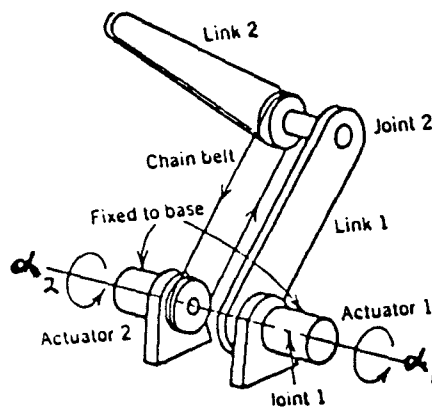
Sample Exam No. 1

1) Consider the two-link (non-planar) robot shown below

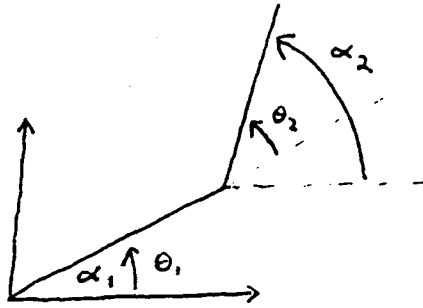


- Describe the workspace of this robot.
- Establish coordinate frames $o_0x_0y_0z_0$, $o_1x_1y_1z_1$, $o_2x_2y_2z_2$ according to the DH-convention.
- Construct the A-matrices, A_1 and A_2 .
- Construct the Jacobian relating the velocity of the end-frame to the joint velocities.
- Are there any singular configurations of this arm? Explain why or why not.

2 A two-link planar arm is shown below



Both driving motors are located on link 0. Motor 2 actuates the elbow via a cable drive. If α_1 , α_2 represent the angles of the motor shafts, find the Jacobian relating end-effector velocity to motor velocity. (Ignore the gear ratio). [Hint: the diagram below should help].



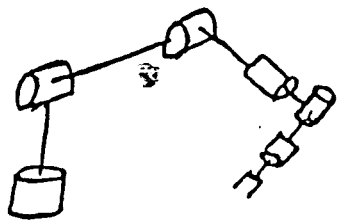
3 For each of the four configurations shown on the next page:

- i) state whether or not the configuration is singular.
- ii) find the rank of the Jacobian matrix.

[Note: You should be able to do this without any computation. Each singularity will cause a reduction of the rank of the Jacobian by 1. Ask yourself, "How many degrees of freedom does the robot have in this configuration?" The answer is the rank of the Jacobian.]

4) If $R_1, R_2 \in SO(3)$ when does $R_1 R_2 = R_2 R_1$?

i.e., under what conditions do two rotations commute?



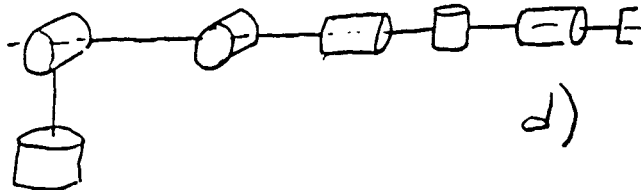
a)



b)



c)



d)