

# Homework 3

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## Instructions

Problems 4.8, 4.9, 4.18, 4.19, 4.24

- 4.8** [12] Given a desired position and orientation of the hand of a three-link planar rotary-jointed manipulator, there are two possible solutions. If we add one more rotational joint (in such a way that the arm is still planar), how many solutions are there?

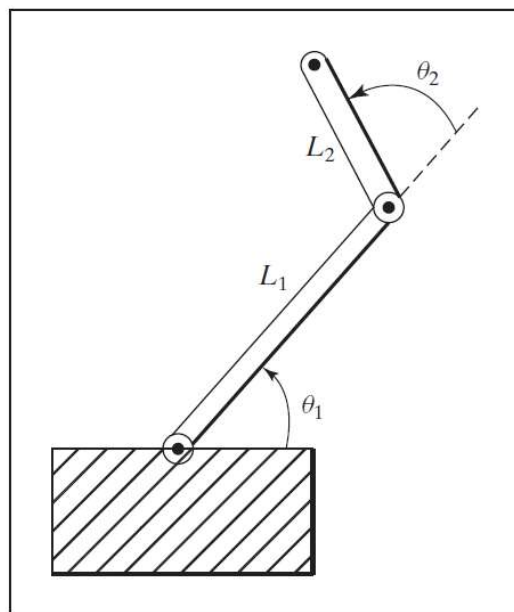


FIGURE 4.13: Two-link planar manipulator (Exercise 4.9).

- 4.9** [26] Figure 4.13 shows a two-link planar arm with rotary joints. For this arm, the second link is half as long as the first—that is,  $l_1 = 2l_2$ . The joint range limits in degrees are

$$\begin{aligned} 0 < \theta_1 < 180, \\ -90 < \theta_2 < 180. \end{aligned}$$

Sketch the approximate reachable workspace (an area) of the tip of link 2.

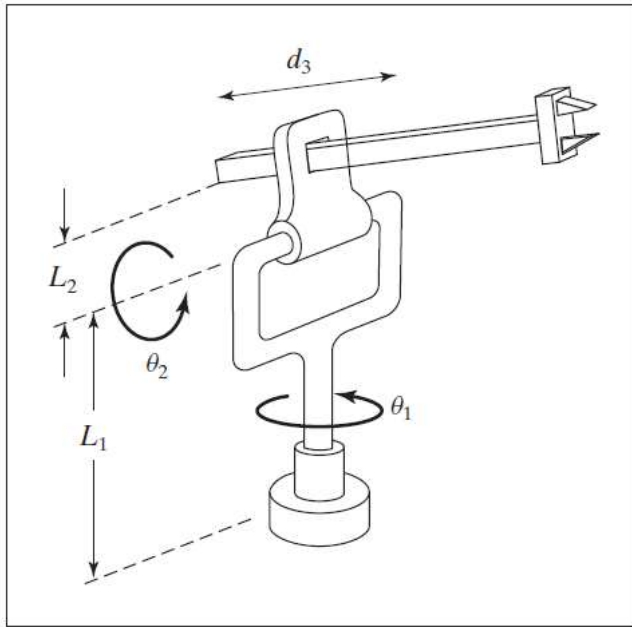


FIGURE 3.37: Three-link *RRP* manipulator (Exercise 3.17).

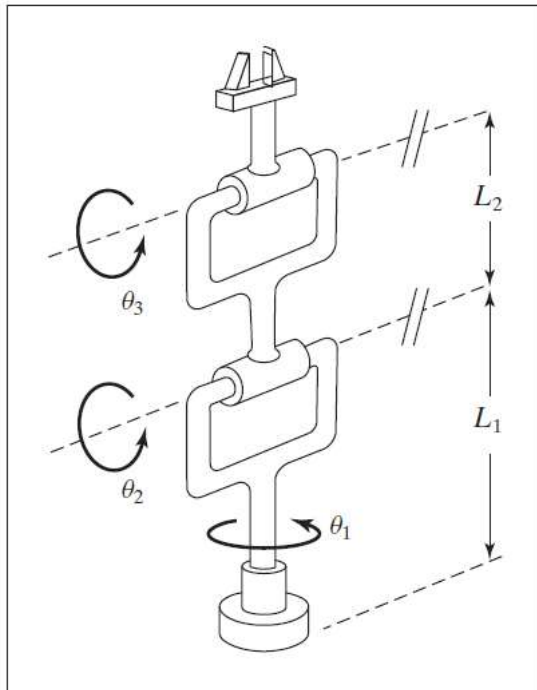


FIGURE 3.38: Three-link *RRR* manipulator (Exercise 3.18).

- 4.18** [15] Consider the *RRP* manipulator shown in Fig. 3.37. How many solutions do the (position) kinematic equations possess?
- 4.19** [15] Consider the *RRR* manipulator shown in Fig. 3.38. How many solutions do the (position) kinematic equations possess?
- 4.24** [20] Given the description of link frame  $\{i\}$  in terms of link frame  $\{i-1\}$ , find the four Denavit–Hartenberg parameters as functions of the elements of  ${}^{i-1}_iT$ .