PROBLEMS

3-1 Verify the statement after equation (3.2.6) that the rotation matrix R has the form (3.2.4) provided assumptions DH1 and DH2 are satisfied.

3-2 Consider the three-link planar manipulator shown in Figure 3-12. Derive the forward kinematic equations using the DH-convention.

3-3 Consider the two-link cartesian manipulator of Figure 3-13. Derive the forward kinematic equations using the DH-convention.

3-4 Consider the two-link manipulator if Figure 3-14 which has joint 1 revolute and joint 2 prismatic. Derive the forward kinematic equations using the DH-convention.

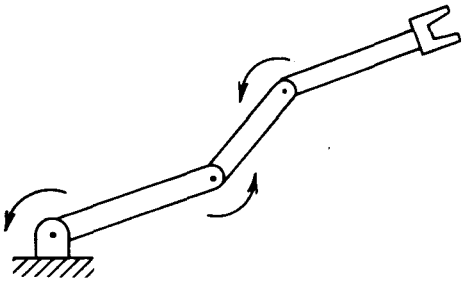

FIGURE 3-12
Three-link planar arm of Problem 3-2.

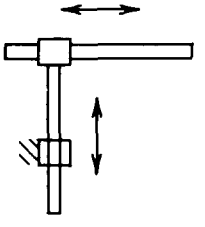

FIGURE 3-13
Two-link cartesian robot of Problem 3-3.

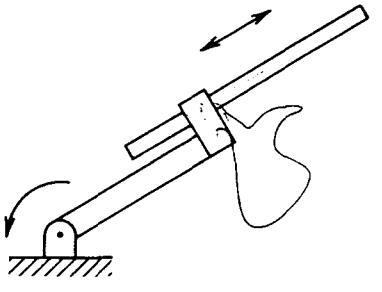

FIGURE 3-14
Two-link planar arm of Problem 3-4.

3-5 Consider the three-link planar manipulator of Figure 3-15. Derive the forward kinematic equations using the DH-convention.

3-6 Consider the three-link articulated robot of Figure 3-16. Derive the forward kinematic equations using the DH-convention.

3-7 Consider the three-link cartesian manipulator of Figure 3-17. Derive the forward kinematic equations using the DH-convention.

3-8 Attach a spherical wrist to the three-link articulated manipulator of Problem 3-6 as shown in Figure 3-18. Derive the forward kinematic equations for this manipulator.

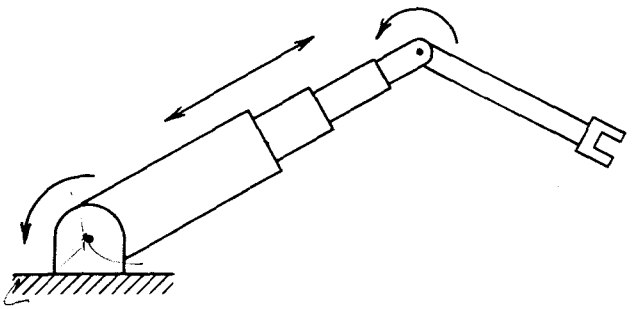

FIGURE 3-15
Three-link planar arm with prismatic joint of Problem 3-5.

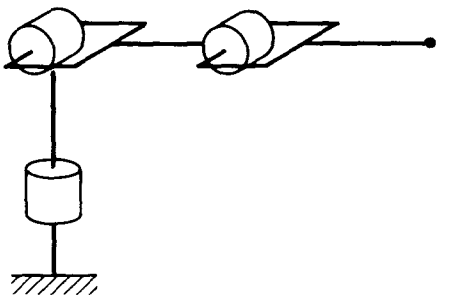

FIGURE 3-16
Three-link articulated robot.

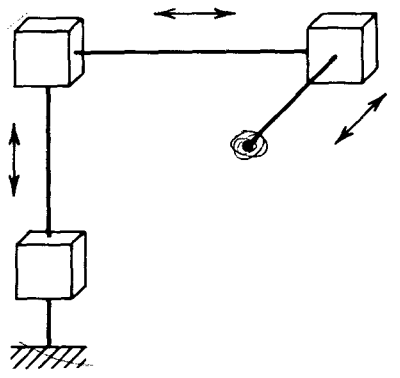

FIGURE 3-17
Three-link cartesian robot.

3-9 Attach a spherical wrist to the three-link cartesian manipulator of Problem 3-7 as shown in Figure 3-19. Derive the forward kinematic equations for this manipulator.

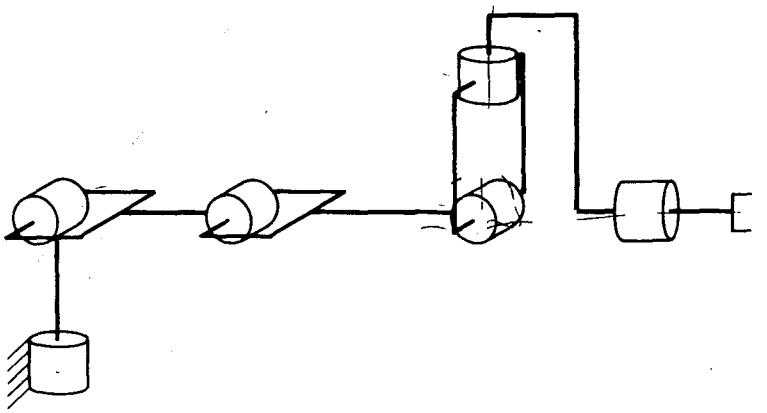

FIGURE 3-18
Elbow manipulator with spherical wrist.

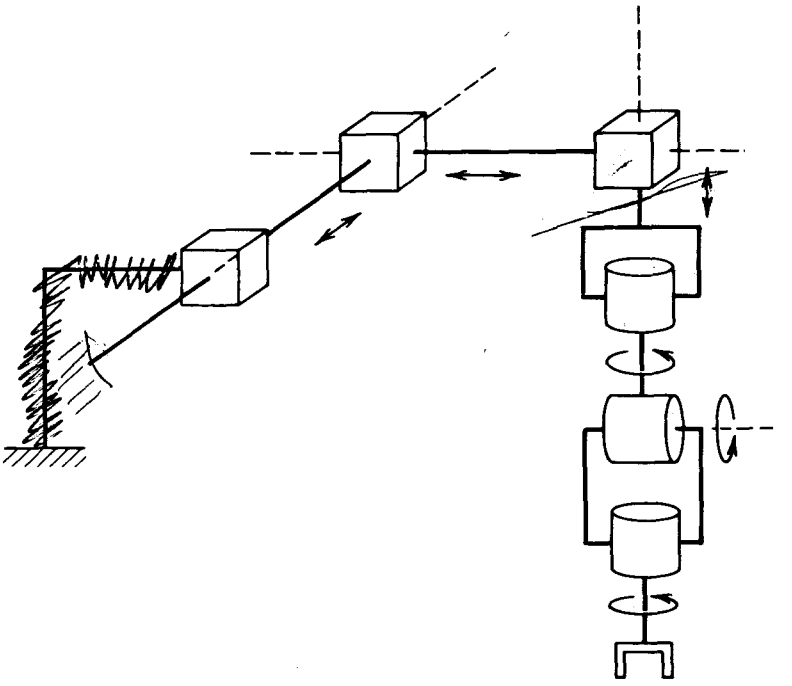

FIGURE 3-19
Cartesian manipulator with spherical wrist.

3-10 Consider the PUMA 260 manipulator shown in Figure 3-20. Derive the complete set of forward kinematic equations, by establishing appropriate D-H coordinate frames, constructing a table of link parameters, forming the A-matrices, etc.

3-11 Repeat Problem 3-9 for the five degree-of-freedom Rhino XR-3 robot shown in Figure 3-21.

3-12 Suppose that a Rhino XR-3 is bolted to a table upon which a coordinate frame $o_s x_s y_s z_s$ is established as shown in Figure 3-22. (The frame $o_s x_s y_s z_s$ is often referred to as the **station frame**.) Given the base frame that you established in Problem 3-11, find the homogeneous transformation T_S^0 relating the base frame to the station frame. Find the homogeneous transformation T_S^6 relating the end-effector frame to the station frame. What is the position and orientation of the end-effector in the station frame when $\theta_1 = \theta_2 = \cdots = \theta_5 = 0$?

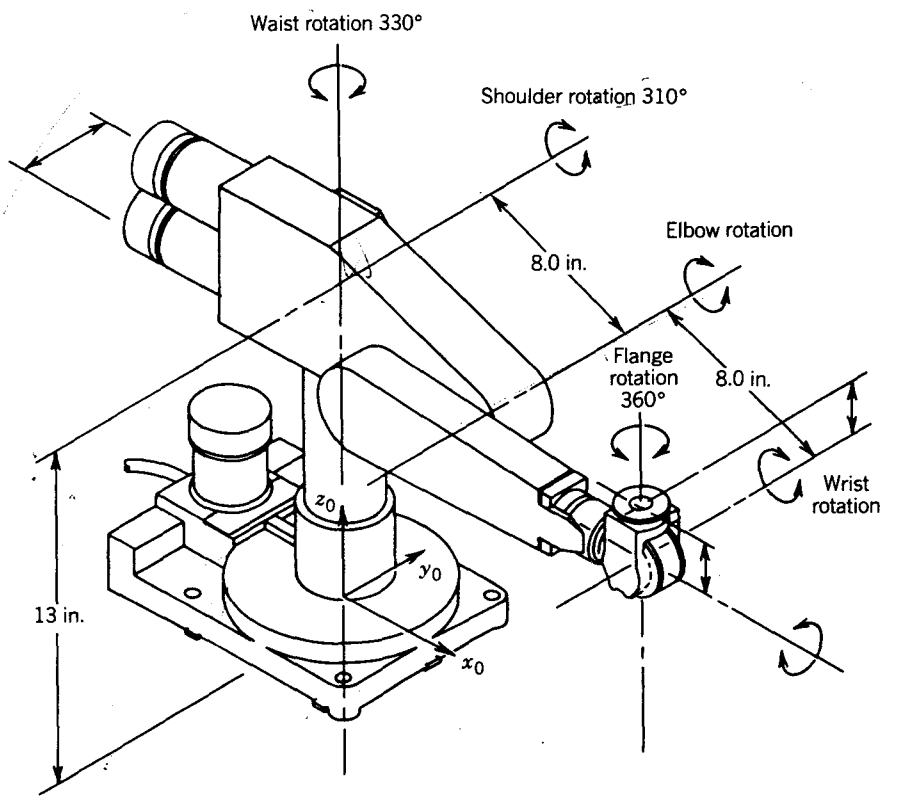

FIGURE 3-20
PUMA 260 manipulator.

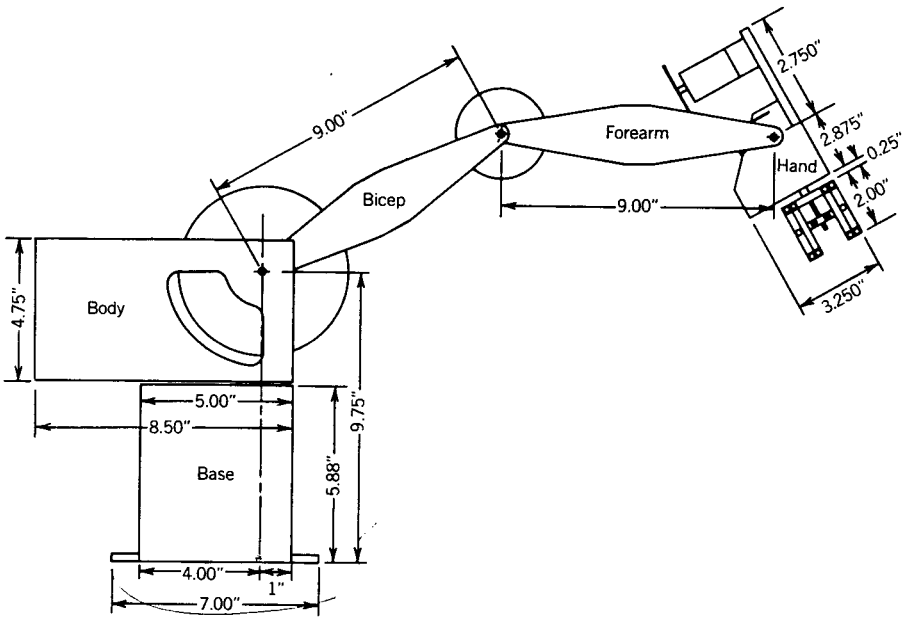

FIGURE 3-21
Rhino XR-3 robot.

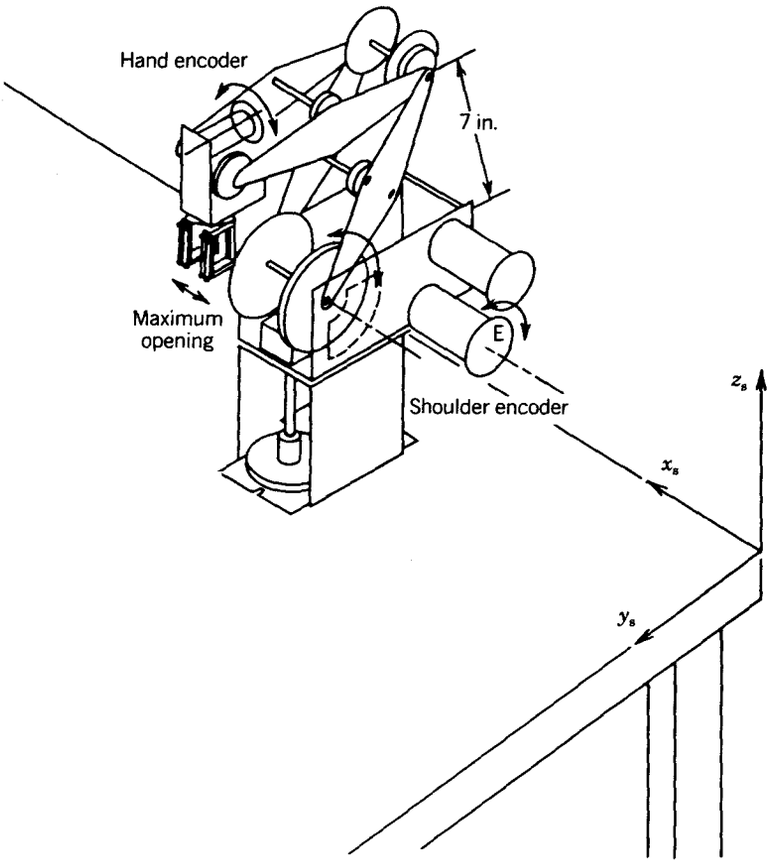

FIGURE 3-22
Rhino robot attached to a table. From: *A Robot Engineering Textbook*, by Mohsen Shahinpoor. Copyright 1987, Harper & Row Publishers, Inc.

3-13 Consider the GMF S-400 robot shown in Figure 3-23. Draw the symbolic representation for this manipulator. Establish DH-coordinate frames and write the forward kinematic equations.

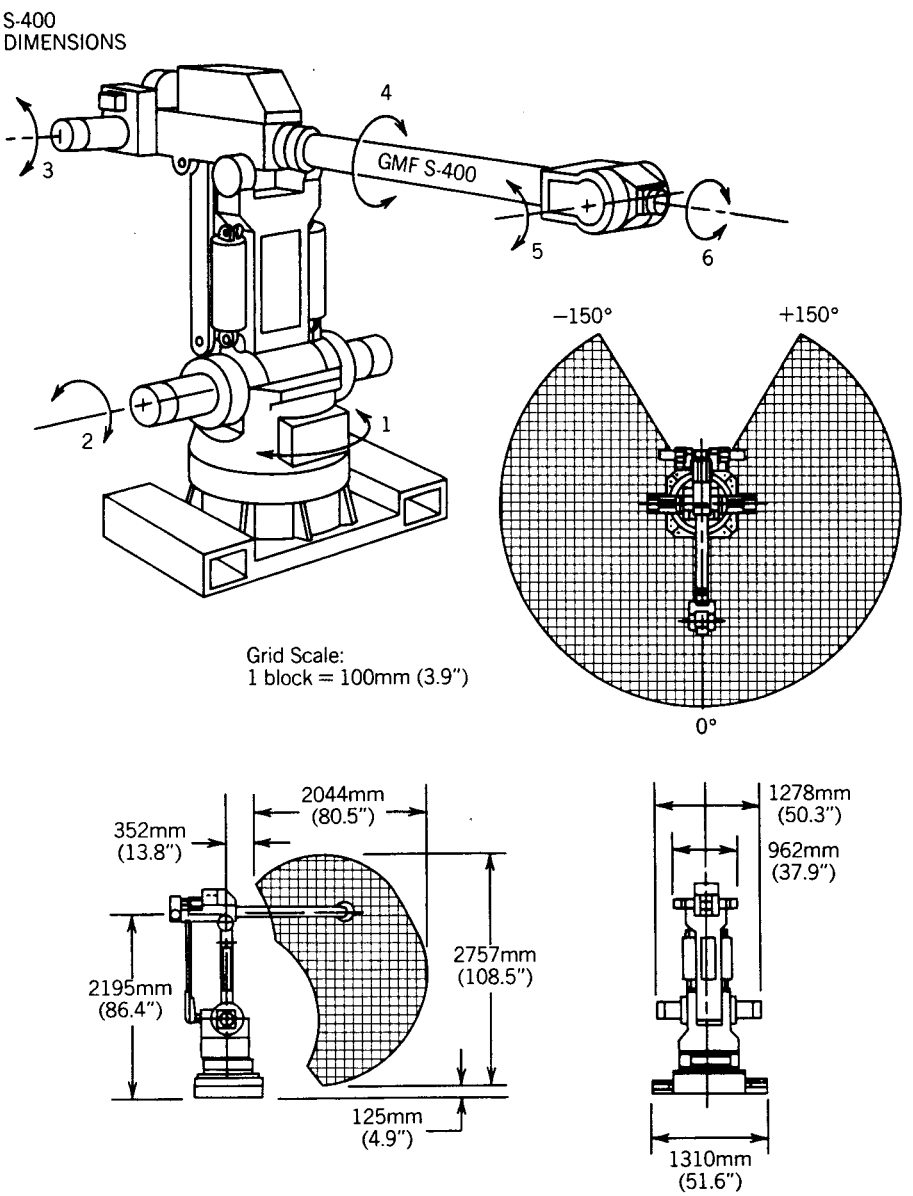

FIGURE 3-23
GMF S-400 robot. (Courtesy GMF Robotics.)