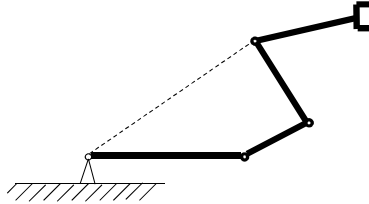


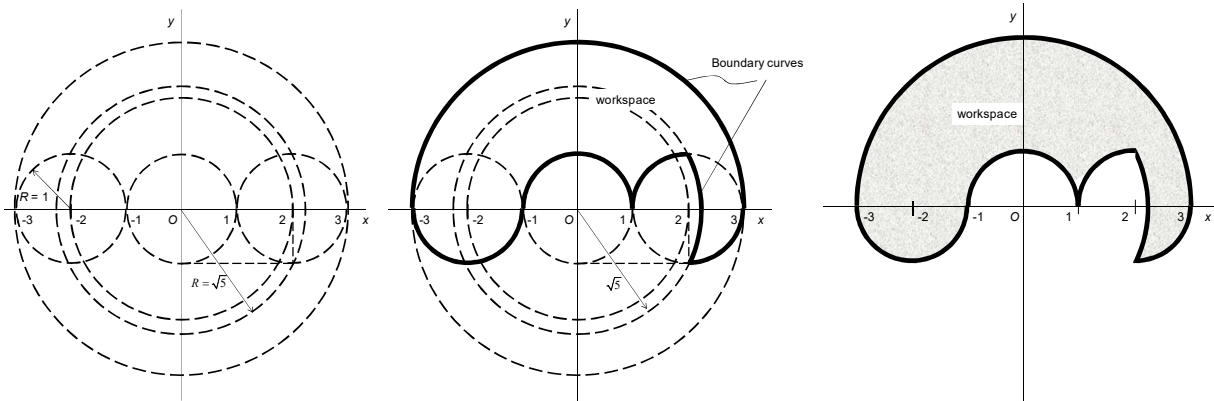
## HW CH4 Solution

Craig 4th ed. Prob.: 4.8, 4.9, 4.18, 4.19, 4.24

4.8) There are an infinite number of solutions. Imagine fixing the last link in position and orientation. Then, the first three links form a “4-bar linkage” which can take on an infinity of positions since it has a degree of freedom.



4.9) First, fix  $\theta_1$  to zero and draw the reachable points set of the tip of link 2 as  $\theta_2$  changes from -90 to 180 degrees. Then rotate this curve about Joint 1 from 0 to 180 degrees to obtain the swept surface.



4.18) Two solutions exist (check by yourself from the number of inverse kinematics solutions).

4.19) Four solutions exist (check by yourself from the number of inverse kinematics solutions).

4.24)

$${}^{i-1}T_i = \begin{bmatrix} \cos \theta_i & -\cos \alpha_i \sin \theta_i & \sin \alpha_i \sin \theta_i & a_i \cos \theta_i \\ \sin \theta_i & \cos \alpha_i \cos \theta_i & -\sin \alpha_i \cos \theta_i & a_i \sin \theta_i \\ 0 & \sin \alpha_i & \cos \alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\therefore \theta_i = \text{atan2}(T_{21}, T_{11}), d_i = T_{34}, a_i = \sqrt{(T_{14}^2 + T_{24}^2)}, \alpha_i = \text{atan2}(T_{32}, T_{33})$$