Step 1. Draw a sketch of the manipulator.

Step 1. Number each link of the manipulator starting from the manipulator base (0) up to the last link n.

Step 1. Identify the robot joints. Number the joint between link i − 1 and i as i.

Step 2. Draw the axis $\hat{Z}_i$ for the joint $i$.

Step 3. Determine the joint length $a_i$ between $\hat{Z}_i$ and $\hat{Z}_{i+1}$.

Step 4. Draw the axis $\hat{X}_i$ along which the joint length is measured.

Step 5. Determine the joint twist $\alpha_i$ as the angle between $\hat{Z}_i$ and $\hat{Z}_{i+1}$ measured around $\hat{X}_i$, in the plane normal to this axis. This angle is positive in the Right-hand sense around $\hat{X}_i$.

Step 6. Determine the joint offset $d_i$ as the distance between $\hat{X}_{i-1}$ and $\hat{X}_i$.

Step 7. Determine the angle $\theta_i$ between $\hat{X}_{i-1}$ and $\hat{X}_i$ around $\hat{Z}_i$, positive in the right-hand sense.

Step 8. For joint $i$, write down the transformation matrix $^{i-1}_iT$ as a function of the parameters $a_{i-1}, \alpha_{i-1}, d_i$ and $\theta_i$.

Step 9. Concatenate the link transformation matrices to find the transformation matrix of the manipulator.
1. Find the DH parameters for the following robotic arm.

Solution:
\( \hat{z}_i \). The Z axis of frame \( \{i\} \) coincides with the joint axis \( i \).

\( \hat{x}_i \). The X axis is located where the mutual perpendicular between joint axis \( i \) and \( i + 1 \) intersects the joint axis \( i \).

\( \hat{y}_i \). The Y axis is selected so as to form a right-handed coordinate system.

\[
\begin{align*}
X_0 \perp Z_1, & \quad X_0 \cap Z_1 \\
X_1 &= Z_1 \times Z_2 \\
X_2 \perp Z_3, & \quad X_2 \cap Z_3 \\
X_3 \perp Z_4, & \quad X_3 \cap Z_4 \\
X_4 &= Z_4 \times Z_5 \\
X_5 \perp Z_6, & \quad X_5 \cap Z_6
\end{align*}
\]

<table>
<thead>
<tr>
<th>Joint ( i )</th>
<th>( \alpha_{i-1} )</th>
<th>( a_{i-1} )</th>
<th>( d_i )</th>
<th>( \theta_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>( L_1 )</td>
<td>( \theta_1 )</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>0</td>
<td>0</td>
<td>( \theta_2 )</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>( L_2 )</td>
<td>0</td>
<td>( \theta_3 )</td>
</tr>
<tr>
<td>4</td>
<td>-90</td>
<td>0</td>
<td>( L_3 + d_4 + L_4 )</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>0</td>
<td>0</td>
<td>( \theta_5 )</td>
</tr>
<tr>
<td>6</td>
<td>-90</td>
<td>0</td>
<td>( L_5 )</td>
<td>( \theta_6 )</td>
</tr>
</tbody>
</table>

\( \alpha_{i-1} = \text{angle}(Z_{i-1}, Z_i) \) around \( X_{i-1} \)

\( a_{i-1} = \text{dist}(O_{i-1}, X_{i-1} \cap Z_i) \) along \( X_{i-1} \)

\( d_i = \text{dist}(X_{i-1}, X_i) \) along \( Z_i \)

\( \theta_i = \text{angle}(X_{i-1}, X_i) \) around \( Z_i \)