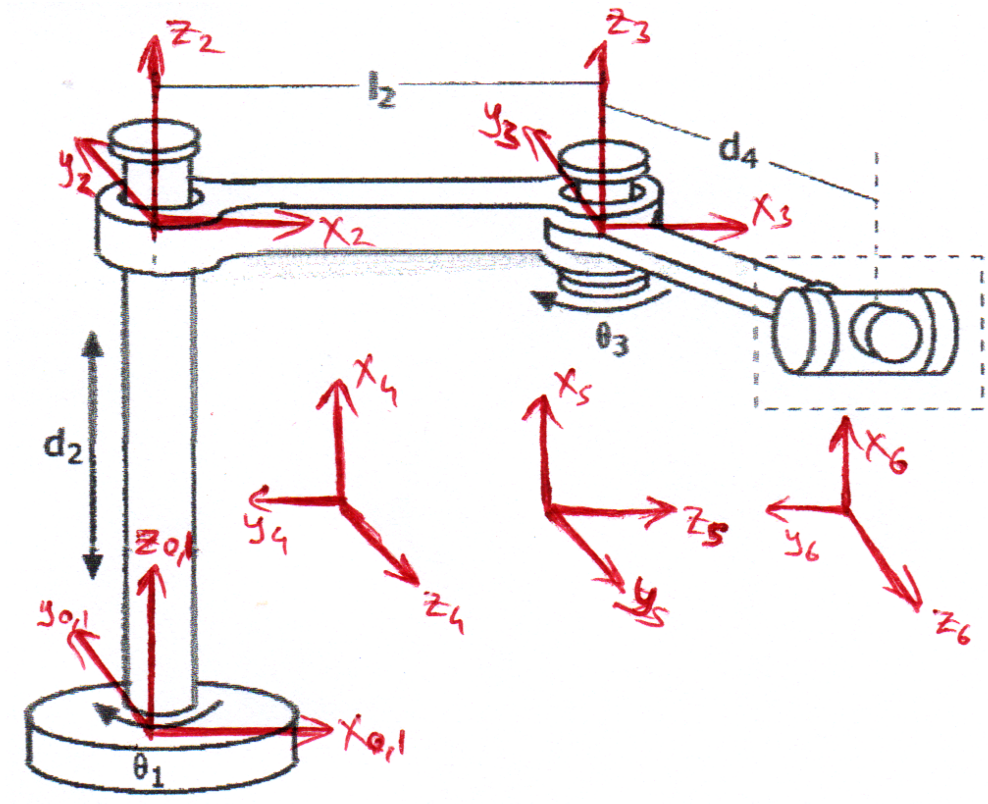
Koordinat Sistemlerinin Yerleşimi



In[1]:=

DH Parametreleri Tablosu

In[2]:=

i	α_{i-1}	a_{i-1}	d_i	θ_i	Değ
1	0	0	0	θ_1	θ_1
2	0	0	d_2	0	d_2
3	0	l_2	0	θ_3	θ_3
4	90	0	d_4	$90+\theta_4$	θ_4
5	90	0	0	θ_5	θ_5
6	-90	0	0	θ_6	θ_6

Out[2]= $\{\{i, \alpha_{-1+i}, a_{-1+i}, d_i, \theta_i, \text{Değ}\}, \{1, 0, 0, 0, \theta_1, \theta_1\}, \{2, 0, 0, d_2, 0, d_2\}, \{3, 0, l_2, 0, \theta_3, \theta_3\}, \{4, 90, 0, d_4, 90+\theta_4, \theta_4\}, \{5, 90, 0, 0, \theta_5, \theta_5\}, \{6, -90, 0, 0, \theta_6, \theta_6\}\}$

Dönüşüm Matrisleri

In[3]:=
```
DH = {{0, 0, 0, θ1}, {0, 0, d2, 0},
   {0, l2, 0, θ3}, {90 Degree, 0, d4, 90 Degree + θ4}} // MatrixForm
```

Out[3]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 0 & \theta_1 \\ 0 & 0 & d_2 & 0 \\ 0 & l_2 & 0 & \theta_3 \\ 90^\circ & 0 & d_4 & 90^\circ+\theta_4 \end{pmatrix}$$

In[4]:=
```
MatrixForm[T01 = {{1, 0, 0, 0}, {0, Cos[DH[[1, 1, 1]]], -Sin[DH[[1, 1, 1]]], 0},
    {0, Sin[DH[[1, 1, 1]]], Cos[DH[[1, 1, 1]]], 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, DH[[1, 1, 2]]}, {0, 1, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{Cos[DH[[1, 1, 4]]], -Sin[DH[[1, 1, 4]]], 0, 0},
    {Sin[DH[[1, 1, 4]]], Cos[DH[[1, 1, 4]]], 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, 0}, {0, 1, 0, 0}, {0, 0, 1, DH[[1, 1, 3]]}, {0, 0, 0, 1}}]
```

Out[4]//MatrixForm=

$$ {}^0_1T = \begin{pmatrix} \mathrm{Cos}[\theta_1] & -\mathrm{Sin}[\theta_1] & 0 & 0 \\ \mathrm{Sin}[\theta_1] & \mathrm{Cos}[\theta_1] & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

In[5]:=
```
MatrixForm[T12 = {{1, 0, 0, 0}, {0, Cos[DH[[1, 2, 1]]], -Sin[DH[[1, 2, 1]]], 0},
    {0, Sin[DH[[1, 2, 1]]], Cos[DH[[1, 2, 1]]], 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, DH[[1, 2, 2]]}, {0, 1, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{Cos[DH[[1, 2, 4]]], -Sin[DH[[1, 2, 4]]], 0, 0},
    {Sin[DH[[1, 2, 4]]], Cos[DH[[1, 2, 4]]], 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, 0}, {0, 1, 0, 0}, {0, 0, 1, DH[[1, 2, 3]]}, {0, 0, 0, 1}}]
```

Out[5]//MatrixForm=

$$ {}^1_2T = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_2 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

In[6]:=
```
MatrixForm[T23 = {{1, 0, 0, 0}, {0, Cos[DH[[1, 3, 1]]], -Sin[DH[[1, 3, 1]]], 0},
    {0, Sin[DH[[1, 3, 1]]], Cos[DH[[1, 3, 1]]], 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, DH[[1, 3, 2]]}, {0, 1, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{Cos[DH[[1, 3, 4]]], -Sin[DH[[1, 3, 4]]], 0, 0},
    {Sin[DH[[1, 3, 4]]], Cos[DH[[1, 3, 4]]], 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, 0}, {0, 1, 0, 0}, {0, 0, 1, DH[[1, 3, 3]]}, {0, 0, 0, 1}}]
```

Out[6]//MatrixForm=

$$ {}^2_3T = \begin{pmatrix} \mathrm{Cos}[\theta_3] & -\mathrm{Sin}[\theta_3] & 0 & l_2 \\ \mathrm{Sin}[\theta_3] & \mathrm{Cos}[\theta_3] & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

In[7]:=
```
MatrixForm[T34 = {{1, 0, 0, 0}, {0, Cos[DH[[1, 4, 1]]], -Sin[DH[[1, 4, 1]]], 0},
    {0, Sin[DH[[1, 4, 1]]], Cos[DH[[1, 4, 1]]], 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, DH[[1, 4, 2]]}, {0, 1, 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{Cos[DH[[1, 4, 4]]], -Sin[DH[[1, 4, 4]]], 0, 0},
    {Sin[DH[[1, 4, 4]]], Cos[DH[[1, 4, 4]]], 0, 0}, {0, 0, 1, 0}, {0, 0, 0, 1}}.
   {{1, 0, 0, 0}, {0, 1, 0, 0}, {0, 0, 1, DH[[1, 4, 3]]}, {0, 0, 0, 1}}]
```

Out[7]//MatrixForm=

$$ {}^3_4T = \begin{pmatrix} -\mathrm{Sin}[\theta_4] & -\mathrm{Cos}[\theta_4] & 0 & 0 \\ 0 & 0 & -1 & -d_4 \\ \mathrm{Cos}[\theta_4] & -\mathrm{Sin}[\theta_4] & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

In[8]:=
```
MatrixForm[T04 = T01.T12.T23.T34 // Simplify]
```

Out[8]//MatrixForm=

$$ {}^0_4T = \begin{pmatrix} -\mathrm{Cos}[\theta_1+\theta_3]\,\mathrm{Sin}[\theta_4] & -\mathrm{Cos}[\theta_1+\theta_3]\,\mathrm{Cos}[\theta_4] & \mathrm{Sin}[\theta_1+\theta_3] & \mathrm{Sin}[\theta_1+\theta_3]\,d_4+\mathrm{Cos}[\theta_1]\,l_2 \\ -\mathrm{Sin}[\theta_1+\theta_3]\,\mathrm{Sin}[\theta_4] & -\mathrm{Cos}[\theta_4]\,\mathrm{Sin}[\theta_1+\theta_3] & -\mathrm{Cos}[\theta_1+\theta_3] & -\mathrm{Cos}[\theta_1+\theta_3]\,d_4+\mathrm{Sin}[\theta_1]\,l_2 \\ \mathrm{Cos}[\theta_4] & -\mathrm{Sin}[\theta_4] & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

Jakobiyen Matrisi

In[9]:= MatrixForm[J = {{D[Sin[$\theta_1 + \theta_3$] d_4 + Cos[θ_1] l_2, θ_1], D[Sin[$\theta_1 + \theta_3$] d_4 + Cos[θ_1] l_2, d_2], D[Sin[$\theta_1 + \theta_3$] d_4 + Cos[θ_1] l_2, θ_3]}, {D[-Cos[$\theta_1 + \theta_3$] d_4 + Sin[θ_1] l_2, θ_1], D[-Cos[$\theta_1 + \theta_3$] d_4 + Sin[θ_1] l_2, d_2], D[-Cos[$\theta_1 + \theta_3$] d_4 + Sin[θ_1] l_2, θ_3]}, {D[d_2, θ_1], D[d_2, d_2], D[d_2, θ_3]}}]

Out[9]//MatrixForm=

$$J = \begin{pmatrix} \cos[\theta_1+\theta_3]\, d_4 - \sin[\theta_1]\, l_2 & 0 & \cos[\theta_1+\theta_3]\, d_4 \\ \sin[\theta_1+\theta_3]\, d_4 + \cos[\theta_1]\, l_2 & 0 & \sin[\theta_1+\theta_3]\, d_4 \\ 0 & 1 & 0 \end{pmatrix}$$

Yörünge Planlaması (Birinci Eklem İçin)

In[10]:= $t_f = 3$

Out[10]= 3

In[11]:= $s_0 = 15$

Out[11]= 15

In[12]:= $s_1 = 0$

Out[12]= 0

In[13]:= $s_2 = \frac{3}{t_f^2}(69 - 15)$

Out[13]= 18

In[14]:= $s_3 = -\frac{2}{t_f^3}(69 - 15)$

Out[14]= -4

In[15]:= $\theta_1[t] = s_0 + s_1 t + s_2 t^2 + s_3 t^3$

Out[15]= $\underline{15 + 18 t^2 - 4 t^3}$ $(\theta_1(t))$

In[16]:= $\theta_1' = D[\theta_1[t], t]$

Out[16]= $\underline{36 t - 12 t^2}$ $(\dot{\theta}_1(t))$

In[17]:= $\theta_1'' = D[\theta_1', t]$

Out[17]= $\underline{36 - 24 t}$ $(\ddot{\theta}_1(t))$

Yörünge Planlaması (İkinci Eklem İçin)

In[18]:= $s_0 = 0.4$

Out[18]= 0.4

In[19]:= $s_1 = 0$

Out[19]= 0

In[20]:= $s_2 = \frac{3}{t_f^2}(0.13 - 0.4)$

Out[20]= -0.09

In[21]:= $s_3 = -\frac{2}{t_f^3}(0.13 - 0.4)$

Out[21]= 0.02

In[22]:= $d_2[t] = s_0 + s_1\,t + s_2\,t^2 + s_3\,t^3$

Out[22]= $0.4 - 0.09\,t^2 + 0.02\,t^3$ $(d_2(t))$

In[23]:= $d_2' = D[d_2[t], t]$

Out[23]= $-0.18\,t + 0.06\,t^2$ $(\dot{d}_2(t))$

In[24]:= $d_2'' = D[d_2', t]$

Out[24]= $-0.18 + 0.12\,t$ $(\ddot{d}_2(t))$

Yörünge Planlaması (Üçüncü Eklem İçin)

In[25]:= $s_0 = 15$

Out[25]= 15

In[26]:= $s_1 = 0$

Out[26]= 0

In[27]:= $s_2 = \frac{3}{t_f^2}(-58 - 23)$

Out[27]= -27

In[28]:= $s_3 = -\frac{2}{t_f^3}(-58 - 23)$

Out[28]= 6

In[29]:= $\theta_3[t] = s_0 + s_1\,t + s_2\,t^2 + s_3\,t^3$

Out[29]= $15 - 27\,t^2 + 6\,t^3$ $(\theta_3(t))$

In[30]:= $\theta_3' = D[\theta_3[t], t]$

Out[30]= $-54\,t + 18\,t^2$ $(\dot{\theta}_3(t))$

In[31]:= $\theta_3'' = D[\theta_3', t]$

Out[31]= $-54 + 36\,t$ $(\ddot{\theta}_3(t))$

Kütle Matrisi

Atalet Tensörlerinin Tanımlanması

In[32]:= MatrixForm[I_{m_1} = {{I_{xx1}, 0, 0}, {0, I_{yy1}, 0}, {0, 0, I_{zz1}}}]

Out[32]//MatrixForm=

$$\begin{pmatrix} i_{xx1} & 0 & 0 \\ 0 & i_{yy1} & 0 \\ 0 & 0 & i_{zz1} \end{pmatrix}$$

In[33]:= $\texttt{MatrixForm}[I_{m_2} = \{\{I_{xx2}, 0, 0\}, \{0, I_{yy2}, 0\}, \{0, 0, I_{zz2}\}\}]$

Out[33]//MatrixForm=

$$\begin{pmatrix} i_{xx2} & 0 & 0 \\ 0 & i_{yy2} & 0 \\ 0 & 0 & i_{zz2} \end{pmatrix}$$

In[34]:= $\texttt{MatrixForm}[I_{m_3} = \{\{I_{xx3}, 0, 0\}, \{0, I_{yy3}, 0\}, \{0, 0, I_{zz3}\}\}]$

Out[34]//MatrixForm=

$$\begin{pmatrix} i_{xx3} & 0 & 0 \\ 0 & i_{yy3} & 0 \\ 0 & 0 & i_{zz3} \end{pmatrix}$$

In[35]:= $\texttt{MatrixForm}\left[\Delta h_1 = \left\{\{0\}, \{0\}, \left\{\frac{l_1}{2}\right\}, \{1\}\right\}\right]$

Out[35]//MatrixForm=

$$\Delta h_1 = \begin{pmatrix} 0 \\ 0 \\ \frac{l_1}{2} \\ 1 \end{pmatrix}$$

In[36]:= $\texttt{MatrixForm}[h_1 = \texttt{T01}.\Delta h_1]$

Out[36]//MatrixForm=

$$h_1 = \begin{pmatrix} 0 \\ 0 \\ \frac{l_1}{2} \\ 1 \end{pmatrix}$$

In[37]:= $\texttt{MatrixForm}[\texttt{R01} = \texttt{T01}[[1 ;; 3, 1 ;; 3]]]$

Out[37]//MatrixForm=

$${}^{0}_{1}R = \begin{pmatrix} \text{Cos}[\theta_1] & -\text{Sin}[\theta_1] & 0 \\ \text{Sin}[\theta_1] & \text{Cos}[\theta_1] & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

In[38]:= $\texttt{MatrixForm}\left[I_1 = \texttt{R01}.I_{m_1}.\texttt{R01}^{\intercal}\right]$ // Simplify

Out[38]//MatrixForm=

$$I_1 = \begin{pmatrix} \text{Cos}[\theta_1]^2\, i_{xx1} + \text{Sin}[\theta_1]^2\, i_{yy1} & \text{Cos}[\theta_1]\,\text{Sin}[\theta_1]\,(i_{xx1} - i_{yy1}) & 0 \\ \text{Cos}[\theta_1]\,\text{Sin}[\theta_1]\,(i_{xx1} - i_{yy1}) & \text{Sin}[\theta_1]^2\, i_{xx1} + \text{Cos}[\theta_1]^2\, i_{yy1} & 0 \\ 0 & 0 & i_{zz1} \end{pmatrix}$$

In[39]:= $\texttt{MatrixForm}[A_1 = \{\{D[h_1[[1, 1]], \theta_1], D[h_1[[1, 1]], d_2], D[h_1[[1, 1]], \theta_3]\},$
$\{D[h_1[[2, 1]], \theta_1], D[h_1[[2, 1]], d_2], D[h_1[[2, 1]], \theta_3]\},$
$\{D[h_1[[3, 1]], \theta_1], D[h_1[[3, 1]], d_2], D[h_1[[3, 1]], \theta_3]\}\}]$

Out[39]//MatrixForm=

$$A_1 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

In[40]:= $\xi_1 = 1$

Out[40]= 1

In[41]:= $\texttt{MatrixForm}[i = \{\{0, 0, 1\}\}^{\mathsf{T}}]$

Out[41]//MatrixForm=

$$\begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

In[42]:= `MatrixForm[z1 = R01.i]`

Out[42]//MatrixForm=

$$\begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

In[43]:= `MatrixForm[ξ1 z1]`

Out[43]//MatrixForm=

$$\begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

In[44]:= `MatrixForm[B1 = {{0, 0, 0}, {0, 0, 0}, {1, 0, 0}}]`

Out[44]//MatrixForm=

$$B_1 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

In[45]:= $\text{MatrixForm}\left[D_{\theta_1} = m_1 A_1^T.A_1 + B_1^T.I_1.B_1\right]$

Out[45]//MatrixForm=

$$D(\theta_1) = \begin{pmatrix} i_{zz1} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

In[46]:= $\text{MatrixForm}\left[\Delta h_2 = \left\{\left\{\frac{l_2}{2}\right\}, \{0\}, \{0\}, \{1\}\right\}\right]$

Out[46]//MatrixForm=

$$\Delta h_2 = \begin{pmatrix} \frac{l_2}{2} \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

In[47]:= `MatrixForm[T02 = T01.T12]`

Out[47]//MatrixForm=

$${}^0_2T = \begin{pmatrix} \text{Cos}[\theta_1] & -\text{Sin}[\theta_1] & 0 & 0 \\ \text{Sin}[\theta_1] & \text{Cos}[\theta_1] & 0 & 0 \\ 0 & 0 & 1 & d_2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

In[48]:= $\text{MatrixForm}[h_2 = \text{T02}.\Delta h_2]$

Out[48]//MatrixForm=

$$h_2 = \begin{pmatrix} \frac{1}{2}\text{Cos}[\theta_1]\, l_2 \\ \frac{1}{2}\text{Sin}[\theta_1]\, l_2 \\ d_2 \\ 1 \end{pmatrix}$$

In[49]:= `MatrixForm[R02 = T02[[1 ;; 3, 1 ;; 3]]]`

Out[49]//MatrixForm=

$${}^0_2R = \begin{pmatrix} \text{Cos}[\theta_1] & -\text{Sin}[\theta_1] & 0 \\ \text{Sin}[\theta_1] & \text{Cos}[\theta_1] & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

In[50]:= $\text{MatrixForm}\left[I_2 = \text{R02}.I_{m_2}.\text{R02}^T\right]$ `// Simplify`

Out[50]//MatrixForm=

$$I_2 = \begin{pmatrix} \text{Cos}[\theta_1]^2\, i_{xx2} + \text{Sin}[\theta_1]^2\, i_{yy2} & \text{Cos}[\theta_1]\,\text{Sin}[\theta_1]\,(i_{xx2} - i_{yy2}) & 0 \\ \text{Cos}[\theta_1]\,\text{Sin}[\theta_1]\,(i_{xx2} - i_{yy2}) & \text{Sin}[\theta_1]^2\, i_{xx2} + \text{Cos}[\theta_1]^2\, i_{yy2} & 0 \\ 0 & 0 & i_{zz2} \end{pmatrix}$$

In[51]:= `MatrixForm[A2 = {{D[h2[[1, 1]], θ1], D[h2[[1, 1]], d2], D[h2[[1, 1]], θ3]}, {D[h2[[2, 1]], θ1], D[h2[[2, 1]], d2], D[h2[[2, 1]], θ3]}, {D[h2[[3, 1]], θ1], D[h2[[3, 1]], d2], D[h2[[3, 1]], θ3]}}]`

Out[51]//MatrixForm=

$$A_2 = \begin{pmatrix} -\frac{1}{2}\mathrm{Sin}[\theta_1]\, l_2 & 0 & 0 \\ \frac{1}{2}\mathrm{Cos}[\theta_1]\, l_2 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

In[52]:= $\xi_2 = 0$

Out[52]= 0

In[53]:= `MatrixForm[z2 = R02.i]`

Out[53]//MatrixForm=

$$\begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

In[54]:= `MatrixForm[ξ2 z2]`

Out[54]//MatrixForm=

$$\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

In[55]:= `MatrixForm[B2 = {{0, 0, 0}, {0, 0, 0}, {1, 0, 0}}]`

Out[55]//MatrixForm=

$$B_2 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

In[56]:= $\mathrm{MatrixForm}\left[D_{d_2} = m_2\, A_2^{\mathsf{T}}.A_2 + B_2^{\mathsf{T}}.I_2.B_2\right]$ `// Simplify`

Out[56]//MatrixForm=

$$D(d_2) = \begin{pmatrix} \mathbb{i}_{zz2} + \frac{1}{4} l_2^2\, m_2 & 0 & 0 \\ 0 & m_2 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

In[57]:= $\mathrm{MatrixForm}\left[\Delta h_3 = \left\{\{0\}, \left\{-\frac{d_4}{2}\right\}, \{0\}, \{1\}\right\}\right]$

Out[57]//MatrixForm=

$$\Delta h_3 = \begin{pmatrix} 0 \\ -\frac{d_4}{2} \\ 0 \\ 1 \end{pmatrix}$$

In[58]:= `MatrixForm[T03 = T01.T12.T23] // Simplify`

Out[58]//MatrixForm=

$$ {}^{0}_{3}T = \begin{pmatrix} \mathrm{Cos}[\theta_1+\theta_3] & -\mathrm{Sin}[\theta_1+\theta_3] & 0 & \mathrm{Cos}[\theta_1]\, l_2 \\ \mathrm{Sin}[\theta_1+\theta_3] & \mathrm{Cos}[\theta_1+\theta_3] & 0 & \mathrm{Sin}[\theta_1]\, l_2 \\ 0 & 0 & 1 & d_2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

In[59]:= `MatrixForm[h3 = T03.Δh3] // Simplify`

Out[59]//MatrixForm=

$$h_3 = \begin{pmatrix} \frac{1}{2}\mathrm{Sin}[\theta_1+\theta_3]\, d_4 + \mathrm{Cos}[\theta_1]\, l_2 \\ -\frac{1}{2}\mathrm{Cos}[\theta_1+\theta_3]\, d_4 + \mathrm{Sin}[\theta_1]\, l_2 \\ d_2 \\ 1 \end{pmatrix}$$

In[60]:= **MatrixForm[R03 = T03[[1 ;; 3, 1 ;; 3]]] // Simplify**

Out[60]//MatrixForm=

$$ {}^{0}_{3}R = \begin{pmatrix} \mathrm{Cos}[\theta_1+\theta_3] & -\mathrm{Sin}[\theta_1+\theta_3] & 0 \\ \mathrm{Sin}[\theta_1+\theta_3] & \mathrm{Cos}[\theta_1+\theta_3] & 0 \\ 0 & 0 & 1 \end{pmatrix} $$

In[61]:= **MatrixForm[I_3 = R03.I_{m_3}.R03$^{\mathsf{T}}$] // Simplify**

Out[61]//MatrixForm=

$$ I_3 = \begin{pmatrix} \mathrm{Cos}[\theta_1+\theta_3]^2\, i_{xx3} + \mathrm{Sin}[\theta_1+\theta_3]^2\, i_{yy3} & \frac{1}{2}\mathrm{Sin}[2(\theta_1+\theta_3)]\,(i_{xx3}-i_{yy3}) & 0 \\ \frac{1}{2}\mathrm{Sin}[2(\theta_1+\theta_3)]\,(i_{xx3}-i_{yy3}) & \mathrm{Sin}[\theta_1+\theta_3]^2\, i_{xx3} + \mathrm{Cos}[\theta_1+\theta_3]^2\, i_{yy3} & 0 \\ 0 & 0 & i_{zz3} \end{pmatrix} $$

In[62]:= **MatrixForm[A_3 = {{D[h_3[[1, 1]], θ_1], D[h_3[[1, 1]], d_2], D[h_3[[1, 1]], θ_3]}, {D[h_3[[2, 1]], θ_1], D[h_3[[2, 1]], d_2], D[h_3[[2, 1]], θ_3]}, {D[h_3[[3, 1]], θ_1], D[h_3[[3, 1]], d_2], D[h_3[[3, 1]], θ_3]}}] // Simplify**

Out[62]//MatrixForm=

$$ A_3 = \begin{pmatrix} \frac{1}{2}\mathrm{Cos}[\theta_1+\theta_3]\, d_4 - \mathrm{Sin}[\theta_1]\, l_2 & 0 & \frac{1}{2}\mathrm{Cos}[\theta_1+\theta_3]\, d_4 \\ \frac{1}{2}\mathrm{Sin}[\theta_1+\theta_3]\, d_4 + \mathrm{Cos}[\theta_1]\, l_2 & 0 & \frac{1}{2}\mathrm{Sin}[\theta_1+\theta_3]\, d_4 \\ 0 & 1 & 0 \end{pmatrix} $$

In[63]:= **ξ_3 = 1**

Out[63]= 1

In[64]:= **MatrixForm[z_3 = R03.i]**

Out[64]//MatrixForm=

$$ \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} $$

In[65]:= **MatrixForm[ξ_3 z_3]**

Out[65]//MatrixForm=

$$ \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} $$

In[66]:= **MatrixForm[B_3 = {{0, 0, 0}, {0, 0, 0}, {1, 0, 1}}]**

Out[66]//MatrixForm=

$$ B_3 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 1 \end{pmatrix} $$

In[67]:= **MatrixForm[D_{θ_3} = m_3 A_3^{T}.A_3 + B_3^{T}.I_3.B_3] // Simplify**

Out[67]//MatrixForm=

$$ D(\theta_3) = \begin{pmatrix} i_{zz3} + \frac{1}{4}\left(d_4^2 + 4\,\mathrm{Sin}[\theta_3]\, d_4\, l_2 + 4\, l_2^2\right) m_3 & 0 & i_{zz3} + \frac{1}{4} d_4 \left(d_4 + 2\,\mathrm{Sin}[\theta_3]\, l_2\right) m_3 \\ 0 & m_3 & 0 \\ i_{zz3} + \frac{1}{4} d_4 \left(d_4 + 2\,\mathrm{Sin}[\theta_3]\, l_2\right) m_3 & 0 & i_{zz3} + \frac{1}{4} d_4^2\, m_3 \end{pmatrix} $$

In[68]:= **MatrixForm[D_{robot} = D_{θ_1} + D_{d_2} + D_{θ_3}] // Simplify**

Out[68]//MatrixForm=

$$ D = \begin{pmatrix} i_{zz1} + i_{zz2} + i_{zz3} + \frac{1}{4} l_2^2\, m_2 + \frac{1}{4} d_4^2\, m_3 + \mathrm{Sin}[\theta_3]\, d_4\, l_2\, m_3 + l_2^2\, m_3 & 0 & i_{zz3} + \frac{1}{4} d_4 \left(d_4 + 2\,\mathrm{Sin}[\theta_3]\, l_2\right) m_3 \\ 0 & m_2 + m_3 & 0 \\ i_{zz3} + \frac{1}{4} d_4 \left(d_4 + 2\,\mathrm{Sin}[\theta_3]\, l_2\right) m_3 & 0 & i_{zz3} + \frac{1}{4} d_4^2\, m_3 \end{pmatrix} $$

In[69]:=