HOMEWORK - 03

1. Position Kinematics - Panda [3.5 points]

In [1]:
```
from sympy import *
from IPython.display import Image,display,HTML
init_printing()

theta,d,a,alpha=symbols('theta,d,a,alpha')
d_1,d_3,d_5,d_7,a_3=symbols('d_1,d_3,d_5,d_7,a_3')
theta_1,theta_2,theta_3,theta_4,theta_5,theta_6,theta_7=symbols('theta_1,theta_2,theta_3,theta_4,theta_5,theta_6,theta_7')
Rot_z_theta=Matrix([[cos(theta),-sin(theta),0,0],
                    [sin(theta),cos(theta),0,0],
                    [0,0,1,0],
                    [0,0,0,1]])
Trans_z_d=Matrix([[1,0,0,0],
                  [0,1,0,0],
                  [0,0,1,d],
                  [0,0,0,1]])
Trans_x_a=Matrix([[1,0,0,a],
                  [0,1,0,0],
                  [0,0,1,0],
                  [0,0,0,1]])
Rot_x_alpha=Matrix([[1,0,0,0],
                   [0,cos(alpha),-sin(alpha),0],
                   [0,sin(alpha),cos(alpha),0],
                   [0,0,0,1]])
```

ROTATION MATRIX COMPUTATION

In [2]:
```
A=Rot_z_theta*Trans_z_d*Trans_x_a*Rot_x_alpha
```

ROTATION MATRIX COMPUTATION FOR EACH JOINT

In [3]:
```
A_1=A.subs({theta:theta_1,d:d_1,a:0,alpha:pi/2})
A_2=A.subs({theta:theta_2,d:0,a:0,alpha:-pi/2})
A_3=A.subs({theta:theta_3,d:d_3,a:a_3,alpha:-pi/2})
A_4=A.subs({theta:theta_4,d:0,a:-a_3,alpha:pi/2})
A_5=A.subs({theta:theta_5,d:d_5,a:0,alpha:pi/2})
A_6=A.subs({theta:theta_6,d:0,a:a_3,alpha:pi/2})
A_7=A.subs({theta:theta_7,d:d_7,a:0,alpha:0})
```

In [4]:
```
A_1
```

Out[4]:

$$\begin{bmatrix}\cos(\theta_1) & 0 & \sin(\theta_1) & 0\\ \sin(\theta_1) & 0 & -\cos(\theta_1) & 0\\ 0 & 1 & 0 & d_1\\ 0 & 0 & 0 & 1\end{bmatrix}$$

In [5]:
```
A_2
```

Out[5]:

$$\begin{bmatrix}\cos(\theta_2) & 0 & -\sin(\theta_2) & 0\\ \sin(\theta_2) & 0 & \cos(\theta_2) & 0\\ 0 & -1 & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

In [6]:
```
A_3
```

Out[6]:

$$\begin{bmatrix}\cos(\theta_3) & 0 & -\sin(\theta_3) & a_3\cos(\theta_3)\\ \sin(\theta_3) & 0 & \cos(\theta_3) & a_3\sin(\theta_3)\\ 0 & -1 & 0 & d_3\\ 0 & 0 & 0 & 1\end{bmatrix}$$

In [7]:
```
A_4
```

Out[7]:

$$\begin{bmatrix}\cos(\theta_4) & 0 & \sin(\theta_4) & -a_3\cos(\theta_4)\\ \sin(\theta_4) & 0 & -\cos(\theta_4) & -a_3\sin(\theta_4)\\ 0 & 1 & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

In [8]:
```
A_5
```

Out[8]:

$$\begin{bmatrix}\cos(\theta_5) & 0 & \sin(\theta_5) & 0\\ \sin(\theta_5) & 0 & -\cos(\theta_5) & 0\\ 0 & 1 & 0 & d_5\\ 0 & 0 & 0 & 1\end{bmatrix}$$

In [9]:
```
A_6
```

Out[9]:

$$\begin{bmatrix}\cos(\theta_6) & 0 & \sin(\theta_6) & a_3\cos(\theta_6)\\ \sin(\theta_6) & 0 & -\cos(\theta_6) & a_3\sin(\theta_6)\\ 0 & 1 & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

In [10]:
```
A_7
```

Out[10]:

$$\begin{bmatrix}\cos(\theta_7) & -\sin(\theta_7) & 0 & 0\\ \sin(\theta_7) & \cos(\theta_7) & 0 & 0\\ 0 & 0 & 1 & d_7\\ 0 & 0 & 0 & 1\end{bmatrix}$$

THE FINAL TRANFORMATION OF EF WRT ORIGIN

In [11]:
```
Transformation=A_1*A_2*A_3*A_4*A_5*A_6*A_7
Transformation
```

Out[11]:

$$\left[\begin{matrix}((((-\sin(\theta_1)\sin(\theta_3)+\cos(\theta_1)\cos(\theta_2)\cos(\theta_3))\cos(\theta_4)+\sin(\theta_2)\sin(\theta_4)\cos(\theta_1))\cos(\theta_5)+(-\sin(\theta_1)\cos(\theta_3)-\sin(\theta_3)\cos(\theta_1)\cos(\theta_2))\sin(\theta_5))\cos(\theta_6) \\ +((-\sin(\theta_1)\sin(\theta_3)+\cos(\theta_1)\cos(\theta_2)\cos(\theta_3))\sin(\theta_4)-\sin(\theta_2)\cos(\theta_1)\cos(\theta_4))\sin(\theta_6))\cos(\theta_7) \\ +(((-\sin(\theta_1)\sin(\theta_3)+\cos(\theta_1)\cos(\theta_2)\cos(\theta_3))\cos(\theta_4)+\sin(\theta_2)\sin(\theta_4)\cos(\theta_1))\sin(\theta_5)-(-\sin(\theta_1)\cos(\theta_3)-\sin(\theta_3)\cos(\theta_1)\cos(\theta_2))\cos(\theta_5))\sin(\theta_7) & -((((-\sin(\theta_1 \; \ldots \\ & +(((-\sin(\theta_1 \; \ldots \\ \\ ((((\sin(\theta_1)\cos(\theta_2)\cos(\theta_3)+\sin(\theta_3)\cos(\theta_1))\cos(\theta_4)+\sin(\theta_1)\sin(\theta_2)\sin(\theta_4))\cos(\theta_5)+(-\sin(\theta_1)\sin(\theta_3)\cos(\theta_2)+\cos(\theta_1)\cos(\theta_3))\sin(\theta_5))\cos(\theta_6) \\ +((\sin(\theta_1)\cos(\theta_2)\cos(\theta_3)+\sin(\theta_3)\cos(\theta_1))\sin(\theta_4)-\sin(\theta_1)\sin(\theta_2)\cos(\theta_4))\sin(\theta_6))\cos(\theta_7) \\ +(((\sin(\theta_1)\cos(\theta_2)\cos(\theta_3)+\sin(\theta_3)\cos(\theta_1))\cos(\theta_4)+\sin(\theta_1)\sin(\theta_2)\sin(\theta_4))\sin(\theta_5)-(-\sin(\theta_1)\sin(\theta_3)\cos(\theta_2)+\cos(\theta_1)\cos(\theta_3))\cos(\theta_5))\sin(\theta_7) & -((((\sin(\theta_1) \; \ldots \\ & +(((\sin(\theta_1) \; \ldots \\ \\ (((\sin(\theta_2)\cos(\theta_3)\cos(\theta_4)-\sin(\theta_4)\cos(\theta_2))\cos(\theta_5)-\sin(\theta_2)\sin(\theta_3)\sin(\theta_5))\cos(\theta_6)+(\sin(\theta_2)\sin(\theta_4)\cos(\theta_3)+\cos(\theta_2)\cos(\theta_4))\sin(\theta_6))\cos(\theta_7) \\ +((\sin(\theta_2)\cos(\theta_3)\cos(\theta_4)-\sin(\theta_4)\cos(\theta_2))\sin(\theta_5)+\sin(\theta_2)\sin(\theta_3)\cos(\theta_5))\sin(\theta_7) & -(((\sin(\theta_2 \; \ldots \\ \\ 0 & \end{matrix}\right.$$

TRANSFOMATION RESULTS FOR GEOMETRICALLY KNOW CONFIGRATIONS

Theta2 is rotated by pi/2

In [12]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:pi/2,
theta_3:0,
theta_4:0,
theta_5:0,
theta_6:0,
theta_7:0})
T_1
```

Out[12]:

$$\begin{bmatrix}0 & 0 & 1 & -d_3-d_5+d_7\\ 0 & -1 & 0 & 0\\ 1 & 0 & 0 & a_3+d_1\\ 0 & 0 & 0 & 1\end{bmatrix}$$

All angles are zero home configration

In [13]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:0,
theta_3:0,
theta_4:0,
theta_5:0,
theta_6:0,
theta_7:0})
T_1
```

Out[13]:

$$\begin{bmatrix}1 & 0 & 0 & a_3\\ 0 & -1 & 0 & 0\\ 0 & 0 & -1 & d_1+d_3+d_5-d_7\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Theta3 is rotated by pi/2

In [14]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:0,
theta_3:pi/2,
theta_4:0,
theta_5:0,
theta_6:0,
theta_7:0})
T_1
```

Out[14]:

$$\begin{bmatrix}0 & 1 & 0 & 0\\ 1 & 0 & 0 & a_3\\ 0 & 0 & -1 & d_1+d_3+d_5-d_7\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Theta4 is rotated by pi/2

In [15]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:0,
theta_3:0,
theta_4:pi/2,
theta_5:0,
theta_6:0,
theta_7:0})
T_1
```

Out[15]:

$$\begin{bmatrix}0 & 0 & -1 & a_3+d_5-d_7\\ 0 & -1 & 0 & 0\\ -1 & 0 & 0 & d_1+d_3\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Theta5 is rotated by pi/2

In [16]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:0,
theta_3:0,
theta_4:0,
theta_5:pi/2,
theta_6:0,
theta_7:0})
T_1
```

Out[16]:

$$\begin{bmatrix}0 & 1 & 0 & 0\\ 1 & 0 & 0 & a_3\\ 0 & 0 & -1 & d_1+d_3+d_5-d_7\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Theta6 is rotated by pi/2

In [17]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:0,
theta_3:0,
theta_4:0,
theta_5:0,
theta_6:pi/2,
theta_7:0})
T_1
```

Out[17]:

$$\begin{bmatrix}0 & 0 & 1 & d_7\\ 0 & -1 & 0 & 0\\ 1 & 0 & 0 & a_3+d_1+d_3+d_5\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Theta7 is rotated by pi/2

In [18]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:0,
theta_3:0,
theta_4:0,
theta_5:0,
theta_6:0,
theta_7:pi/2})
T_1
```

Out[18]:

$$\begin{bmatrix}0 & -1 & 0 & a_3\\ -1 & 0 & 0 & 0\\ 0 & 0 & -1 & d_1+d_3+d_5-d_7\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Theta 7 is roated by pi/2

In [19]:
```
T_1=Transformation.subs({theta_1:0,
theta_2:0,
theta_3:0,
theta_4:0,
theta_5:0,
theta_6:0,
theta_7:pi/2})
T_1
```

Out[19]:

$$\begin{bmatrix}0 & -1 & 0 & a_3\\ -1 & 0 & 0 & 0\\ 0 & 0 & -1 & d_1+d_3+d_5-d_7\\ 0 & 0 & 0 & 1\end{bmatrix}$$

In [ ]: