Assignment 2

Task1

Task 1

To prove:

$RS(a)R^T = S(Ra)$ where R is a rotation matrix

for an operator R; $R(a \times b) = (Ra) \times (Rb)$

Let $\vec{a} = a$ and $\vec{b} = I$.

we also know that $S(a)P = a \times p$

$$RS(a)R^T = RS(a)R^T I. = R(a \times R^T I)$$

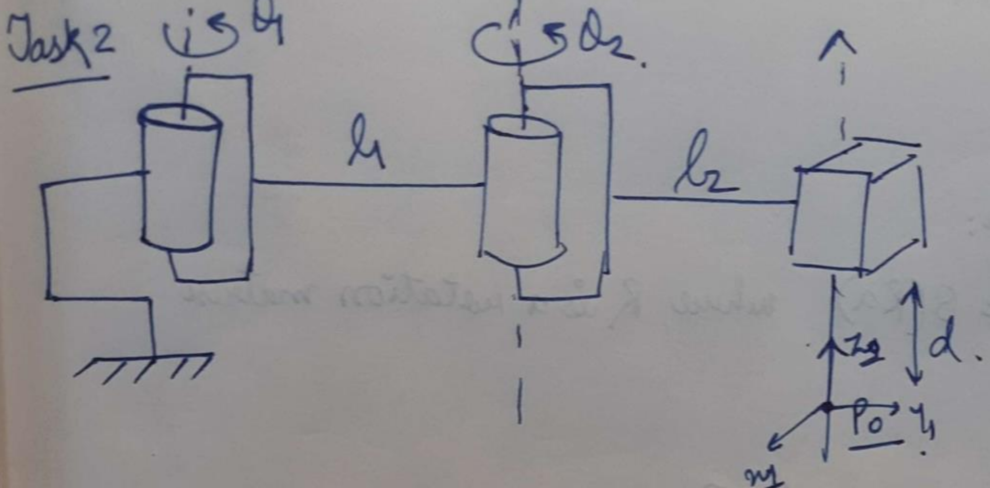
$$= (R(a)) \times (R R^T I)$$

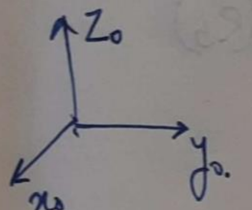
$$= Ra \times I. = \underline{S(Ra)\, I}$$

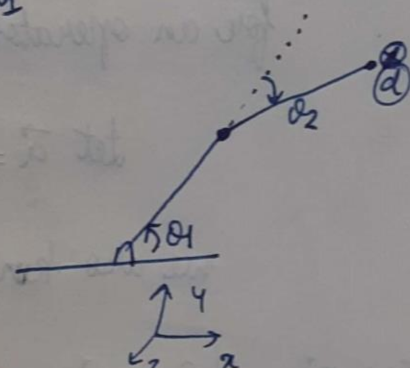
$$= \underline{S(Ra)}.$$

Task 2

Task 2







$$R = \begin{bmatrix} \cos(\theta_1+\theta_2) & -\sin(\theta_1+\theta_2) & 0 \\ \sin(\theta_1+\theta_2) & \cos(\theta_1+\theta_2) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$H_0^{P_0} = \begin{bmatrix} \cos(\theta_1+\theta_2) & -\sin(\theta_1+\theta_2) & 0 & l_1 \cos\theta_1 + l_2 \cos(\theta_1+\theta_2) \\ \sin(\theta_1+\theta_2) & \cos(\theta_1+\theta_2) & 0 & l_1 \sin\theta_1 + l_2 \sin(\theta_1+\theta_2) \\ 0 & 0 & 1 & -d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Task 6

There are several types of gearboxes that are commonly used with motors in robotic applications. Some of the most common types include:

Harmonic Drive: This type of gearbox is known for its high precision and compact size. It is commonly used in robotic joints and can achieve high reduction ratios in a single stage. However, it can be expensive and may have limited torque capacity.

Cycloid Drive: This type of gearbox is also known for its high precision and compact size. It is commonly used in robotic joints and can achieve high reduction ratios in a single stage. However, it can be expensive and may have limited torque capacity.

Planetary Gearbox: This type of gearbox is known for its high torque capacity and efficiency. It is commonly used in robotic arms and other applications where high torque is required. However, it can be larger and more complex than other types of gearboxes3.

Task 7

Position vectors of end effector.

$x = l_1 \cos\theta_1 + l_2 \cos(\theta_1+\theta_2)$

$y = l_1 \sin\theta_1 + l_2 \sin(\theta_1+\theta_2)$

$z = -d.$

Task 9

Position vectors of end effector.

$$x = l_1 \cos\theta_1 + l_2 \cos(\theta_1+\theta_2) + l_3 \cos(\theta_1+\theta_2+\theta_3)$$

$$y = l_1 \sin\theta_1 + l_2 \sin(\theta_1+\theta_2) + l_3 \sin(\theta_1+\theta_2+\theta_3)$$

$$z = 0.$$

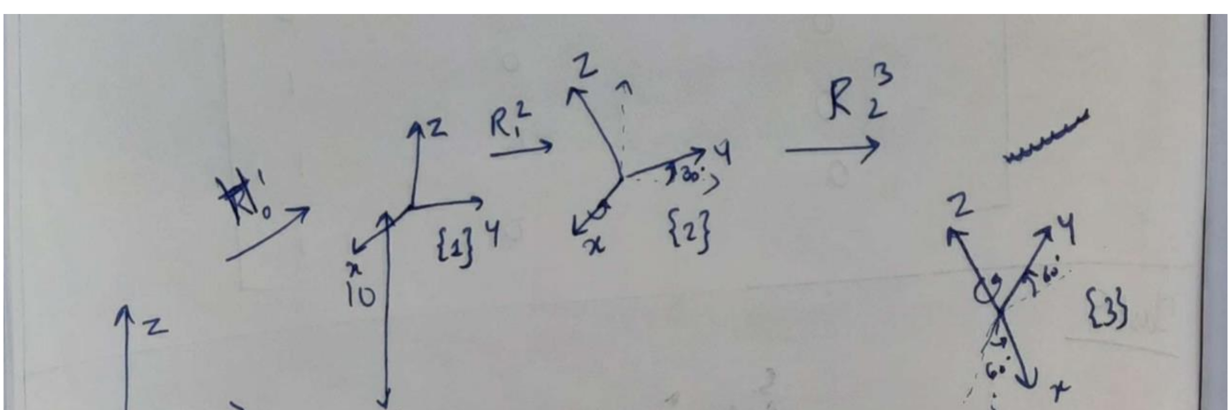
$$\dot{x} = -l_1 \sin\theta_1 \dot{\theta}_1 - l_2 \sin(\theta_1+\theta_2)(\dot{\theta}_1+\dot{\theta}_2) - l_3 \sin(\theta_1+\theta_2+\theta_3)(\dot{\theta}_1+\dot{\theta}_2+\dot{\theta}_3)$$

$$\dot{y} = l_1 \cos\theta_1 \dot{\theta}_1 + l_2 \cos(\theta_1+\theta_2)(\dot{\theta}_1 + \dot{\theta}_2) \ldots$$

$$J = \begin{bmatrix} -l_1 s_1 - l_2 s_{12} - l_3 s_{123} & -l_2 s_{12} - l_3 s_{123} & -l_3 s_{123} \\ l_1 c_1 + l_2 c_{12} + l_3 c_{123} & l_2 c_{12} + l_3 c_{123} & l_3 c_{123} \\ 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

Task 5

Matrix multiplication has been done in python



```python
import numpy as np

T01 = np.array([[1,0,0,0],[0,1,0,0],[0,0,1,10],[0,0,0,1]])
T12 = np.array([[1,0,0,0],[0,np.cos(30),-np.sin(30),0],[0,np.sin(30),np.cos(30),0],[0,0,0,1]])
T23 = np.array([[np.cos(60),-np.sin(60),0,0],[np.sin(60),np.cos(60),0,0],[0,0,1,10],[0,0,0,1]])
T34 = np.array([[1,0,0,0],[0,1,0,0],[0,0,1,3],[0,0,0,1]])
T04 = np.dot(np.dot(np.dot(T01,T12),T23),T34)
print(T04[0,3],T04[1,3],T04[2,3])
```

```
x= 0.0 y= 12.844411113207205 z= 12.005268848538593
```