1.

Q1) We know,

- $S(a)\,p = a \times p \quad \text{--- (1)}$
- $R(a \times b) = Ra \times Rb \quad \text{--- (2)}$

$$\therefore \quad R\,(S(a))\,R^T b = R\,(a \times R^T b) \qquad \text{(from (1))}$$

$$= (Ra) \times (R R^T b) \qquad \text{(from (2))}$$

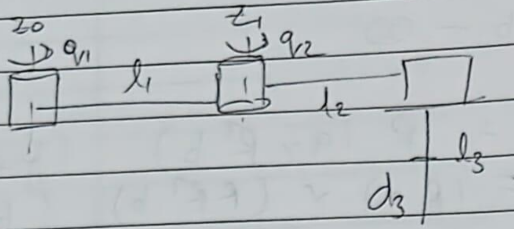
$$= (Ra) \times b$$

$$= S\,(Ra)\,b \qquad \text{(from (1))}$$

$$\therefore \quad R\,(S(a))\,R^T = S\,(Ra)$$

2.

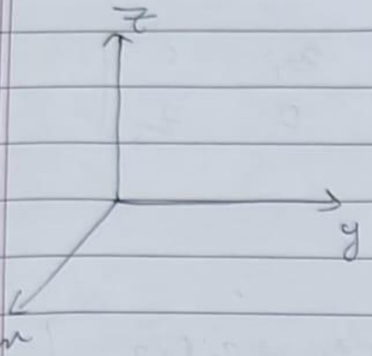
Q2) RRP Scara



- $R_0^1 = R_{z,q_1}$, $d_0^1 = 0$
- $R_1^2 = R_{z,q_2}$, $d_1^2 = [l_1, 0, 0]^T$
- $R_2^3 = R_{z,0}$, $d_2^3 = [l_2, 0, d_3]^T$
- $P_3 = [0, 0, l_3]^T$

$$\begin{bmatrix} P_0 \\ 1 \end{bmatrix} = H_0^1 H_1^2 H_2^3 \begin{bmatrix} P_3 \\ 1 \end{bmatrix}$$

Q5)



- $R_0^1 = R_{x,\pi/6}$, $d_0^1 = [0, 0, 10]^T$
- $R_1^2 = R_{z,\pi/3}$, $d_1^2 = [0, 0, 0]^T$
- $P_2 = [0, 0, 3]^T$

$$T_0^1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \sqrt{3}/2 & -1/2 & 0 \\ 0 & 1/2 & \sqrt{3}/2 & 10 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T_0^2 = \begin{bmatrix} 1/2 & -\sqrt{3}/2 & 0 & 0 \\ \sqrt{3}/2 & 1/2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} P_0 \\ 1 \end{bmatrix} = T_0^1 \cdot T_0^2 \cdot \begin{bmatrix} P_3 \\ 1 \end{bmatrix}$$

$$P_0 = [0\hat{i}, -1.5\hat{j}, 12.6\hat{k}]$$

5.

6.

Planetary Gearbox:
Pros: Compact size, high torque transmission efficiency, and better load distribution due to multiple gear stages. They offer a good balance between size and performance.
Cons: Can be more complex and expensive to manufacture. Some designs might have higher backlash.
Application: Often used in robotic arms, industrial robots, and automation systems where space is limited and high torque is required.

Spur Gearbox:
Pros: Simple and cost-effective, with high efficiency in a single-stage design. They provide consistent torque and speed transmission.
Cons: Can produce noise and vibration due to the direct engagement of teeth. Not as compact as planetary gearboxes.
Application: Commonly used in applications where noise is not a significant concern, such as manufacturing equipment and conveyor systems.

Worm Gearbox:
Pros: High reduction ratios in a compact design, self-locking property (can hold position without external brake), and good shock load handling.
Cons: Lower efficiency compared to other types due to sliding action between the worm and gear.
Application: Often used in applications where self-locking capability is crucial, such as lifting mechanisms in robotics and conveyor belt systems.

Harmonic Drive Gearbox:
Pros: High precision, zero backlash, compact size, and lightweight. Offers excellent positional accuracy.
Cons: Can be expensive and limited in torque capacity.
Application: Commonly used in applications requiring precise motion control, like robotic arms for delicate tasks and space-constrained environments.

In most drone setups, gearboxes aren't used with motors. Drones aim to stay lightweight and energy-efficient for flying. Gearboxes can add extra weight and friction, which could decrease the flying efficiency. So, typical drones have motors directly linked to propellers without gearboxes. But exceptional cases like heavy-duty or industrial drones might use gearboxes. These drones need the extra torque and power that a gearbox can offer, even if it comes with some efficiency trade-offs.

References:
https://wiki.wpi.edu/robotics/Gears

7.

Page :

Q7) We know, for SCARA RRP (

$$J = \begin{bmatrix} z_0 \times (O_4 - O_0) & z_1 \times (O_4 - O_1) & z_2 & 0 \\ z_0 & z_1 & 0 & z_3 \end{bmatrix}$$

where,

$$O_1 = \begin{bmatrix} a_1 c_1 \\ a_1 s_1 \\ 0 \end{bmatrix} \qquad O_2 = \begin{bmatrix} a_1 c_1 + a_2 c_{12} \\ a_1 s_1 + a_2 s_{12} \\ 0 \end{bmatrix}$$

$$O_4 = \begin{bmatrix} a_1 c_1 + a_2 c_{12} \\ a_1 s_1 + a_2 s_{12} \\ d_3 + d_4 \end{bmatrix}$$

$$z_0 = z_1 = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$z_2 = z_3 = \begin{bmatrix} 0 \\ 0 \\ -1 \end{bmatrix}$$

$$\therefore J = \begin{bmatrix} (-a_1 s_1 - a_2 s_{12}) & (-a_2 s_{12}) & 0 & 0 \\ (a_1 c_1 + a_2 c_{12}) & (a_2 c_{12}) & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & -1 \end{bmatrix}$$