# COMS W4733 Computational Aspects of Robotics -- HW2

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## Problem 1

## Problem 2

(a)

$$J_p(q) = \begin{bmatrix} \frac{\partial p_x}{\partial q_1} & \frac{\partial p_x}{\partial q_2} & \frac{\partial p_x}{\partial q_3} \\ \frac{\partial p_y}{\partial q_1} & \frac{\partial p_y}{\partial q_2} & \frac{\partial p_y}{\partial q_3} \\ \frac{\partial p_z}{\partial q_1} & \frac{\partial p_z}{\partial q_2} & \frac{\partial p_z}{\partial q_3} \end{bmatrix}$$

$$= \begin{bmatrix} -(L_1 + L_2 c_2 + L_3 c_{23}) s_1 & -L_2 c_1 s_2 - L_3 c_1 s_{23} & -L_3 c_1 s_{23} \\ (L_1 + L_2 c_2 + L_3 c_{23}) c_1 & -L_2 s_1 s_2 - L_3 s_1 s_{23} & -L_3 s_1 s_{23} \\ 0 & L_2 c_2 + L_3 c_{23} & L_3 c_{23} \end{bmatrix}$$

| **Link** | $a_i$ | $\alpha_i$ | $d_i$ | $\theta_i$ |
|---|---|---|---|---|
| 1 | $L_1$ | 90 | 0 | $\theta_1$ |
| 2 | $L_2$ | 0 | 0 | $\theta_2$ |
| 3 | $L_3$ | 0 | 0 | $\theta_3$ |

## Problem 3

(a)

$$
\begin{equation}

```
\begin{split}
J_p(q) &=
\begin{bmatrix}
\frac{\partial p_x}{\partial q_1} & \frac{\partial p_x}{\partial q_2} & \frac{\partial p_x}
{\partial q_3} \\
\frac{\partial p_y}{\partial q_1} & \frac{\partial p_y}{\partial q_2} & \frac{\partial p_y}
{\partial q_3}  \\
\frac{\partial p_z}{\partial q_1} & \frac{\partial p_z}{\partial q_2} & \frac{\partial p_z}
{\partial q_3}
\end{bmatrix}\\
&= \begin{bmatrix}
-(L_1+L_2c_2+L_3c_{23})s_1 & -L_2c_1s_2-L_3c_1s_{23} & -L_3c_1s_{23} \\
 (L_1+L_2c_2+L_3c_{23})c_1 & -L_2s_1s_2-L_3s_1s_{23} & -L_3s_1s_{23}  \\
0 & L_2c_2+L_3c_{23} & L_3c_{23}
\end{bmatrix}
\end{split}
\end{equation}
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$$

$$J_p(q) = \begin{bmatrix} \frac{\partial p_x}{\partial q_1} & \frac{\partial p_x}{\partial q_2} & \frac{\partial p_x}{\partial q_3} \\ \frac{\partial p_y}{\partial q_1} & \frac{\partial p_y}{\partial q_2} & \frac{\partial p_y}{\partial q_3} \\ \frac{\partial p_z}{\partial q_1} & \frac{\partial p_z}{\partial q_2} & \frac{\partial p_z}{\partial q_3} \end{bmatrix}$$

$$= \begin{bmatrix} -(L_1 + L_2c_2 + L_3c_{23})s_1 & -L_2c_1s_2 - L_3c_1s_{23} & -L_3c_1s_{23} \\ (L_1 + L_2c_2 + L_3c_{23})c_1 & -L_2s_1s_2 - L_3s_1s_{23} & -L_3s_1s_{23} \\ 0 & L_2c_2 + L_3c_{23} & L_3c_{23} \end{bmatrix}$$

| **Link** | $a_i$ | $\alpha_i$ | $d_i$ | $\theta_i$ |
|---|---|---|---|---|
| 1 | 1 | 90 | 0 | $\theta_1$+90 |
| 2 | 0 | -90 | $d_2$+2 | 0 |
| 3 | 2 | 0 | 0 | $\theta_3$-90 |