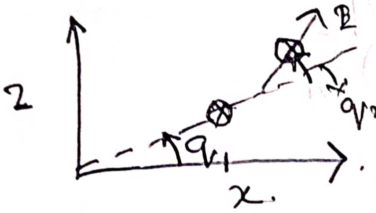
2) The joints of the manipulator will experience different amount of torques depending on their location in the structure of the manipulator. Joint actuators are designed and manufactured in different sizes and with different torque ratings.



Each link needs to support outboard links. Every link supports forces and moments.

The forces and moments depends on

a) pose of the link.

b) speed of link.

c) acceleration of link.

d) Gravity.

Since the actuator generates the force that will move the link, then it must produce a force greater than or equal to the force produced due to the link and possible payload.

It is necessary to determine the maximum torque required for each joint motor.

The second step is choosing joint motors based on the calculated torque values at the respective joints,

Stepper motor output good amount of torque as well as high precision.

The dynamics of robot arm is described using Lagrange Euler:

$$M(q)\cdot\ddot{q} + C(q,\dot{q})\dot{q} + G(q) = \tau.$$

where q is the joint variable vector, $M(q)$ is the completed inertia matrix, $C(q,\dot{q})\dot{q}$ is the centripetal and Coriolis torque vector, $G(q)$ is gravitational torque vector.

The robot has two joint variables that require lifting.

$$M(q) = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}$$

$$M_{11} = \frac{1}{4} m_1 L_1^2 + m_2 L_1^2 + J$$

$$M_{12} = M_{21} = \frac{1}{2} m_2 L_1 L_2 \cos(q_1 - q_2)$$

$$M_{22} = J + \frac{1}{4} m_2 L_2^2.$$

We have used Newton Laws for translation motion and Eulerian Law for rotational motion.

Determine the translational and angular velocity of COM of each link.

$C_{11} = 0 \quad C_{12} = \frac{1}{2} m_2 L_1 L_2 \sin(q_1 - q_2)\dot{q}_2$

$C_{21} = \frac{1}{2} m_2 L_1 . L_2 \sin(q_2 - q_1)\dot{q}_1$

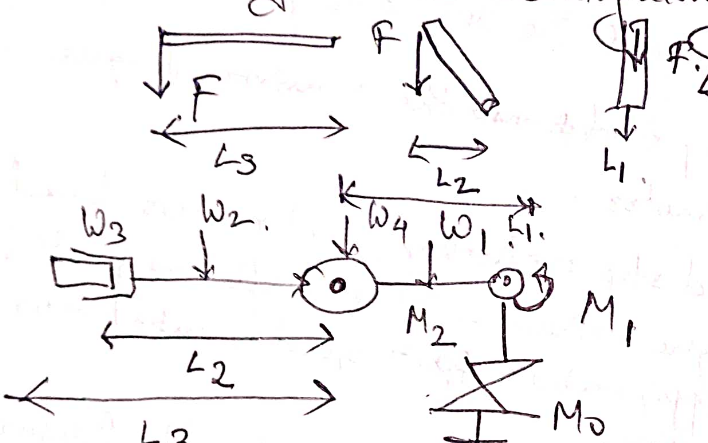
$C_{22} = 0.$

Torque (τ) = Force (F) $\times$ Length (L)

$\tau = F \times L. \quad F = W = m \times g.$

~~Ans.~~ $\tau = m \times g \times L. \quad \tau = W \times L.$

three forces are occuring along link length as one mass with three translations



In the figure a link of the length L of the is rotated clockwise. Only the perpendicular component of the length between the pivot and force is taken into consideration. The distance decreases from L3 to L1. Since the equation for torque is length multiplied by force, greatest value is obtained using L3 since F does not change.

The robotic joint

Torque about Joint 1.

$M_1 = \frac{L_1}{2} * W_1 + L_1 * W_4 + (L_1 + \frac{L_2}{2}) * W_2 + (L_1 + L_3) * W_3$

The length will be rotated counter clockwise and same effect may be obsen

Torque about joint 2.

$M_2 = \frac{L_2}{2} * W_2 + L_3 * W_3$

W_1 is weight of Link 1, $W_2 \rightarrow$ weight of Link 2,

W_3 weight of Load, $W_4 \rightarrow$ weight of actuator.

$L1 \rightarrow$ Length of Link 1 $L2 \rightarrow$ length of Link L2.

L load $\rightarrow$ Length of Load (end effector)

$L.3 =$ Length2 $+ (1/2 * L$ load$)$ $M_0 =$ Base actuator

$M1 =$ Actuator 1 (Joint 1) $M2 =$ Actuator 2.

For the

w_1