Exam 2024

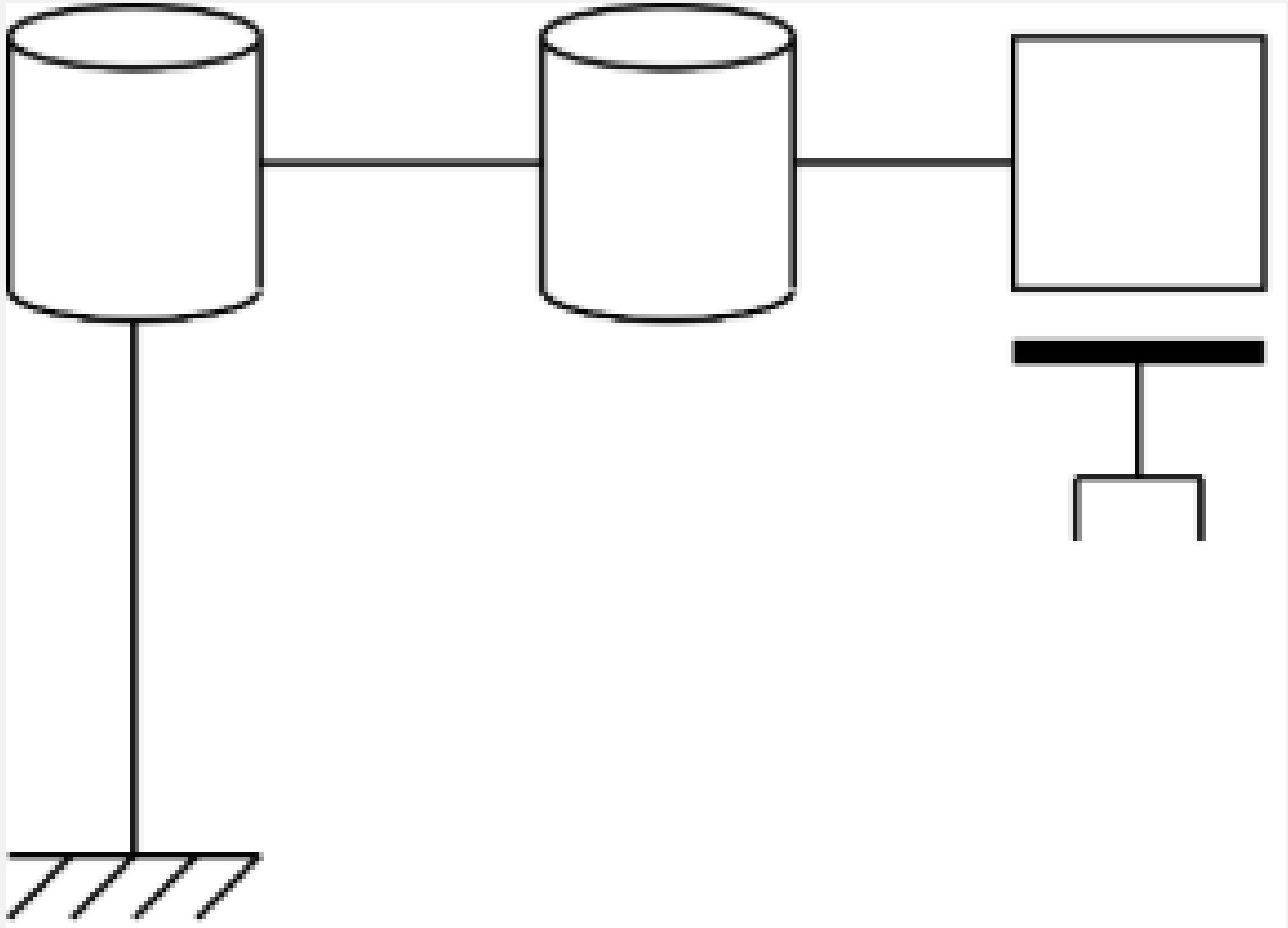
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Frida Berge

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Manipulator 1

A manipulator of which type is displayed in the following image?



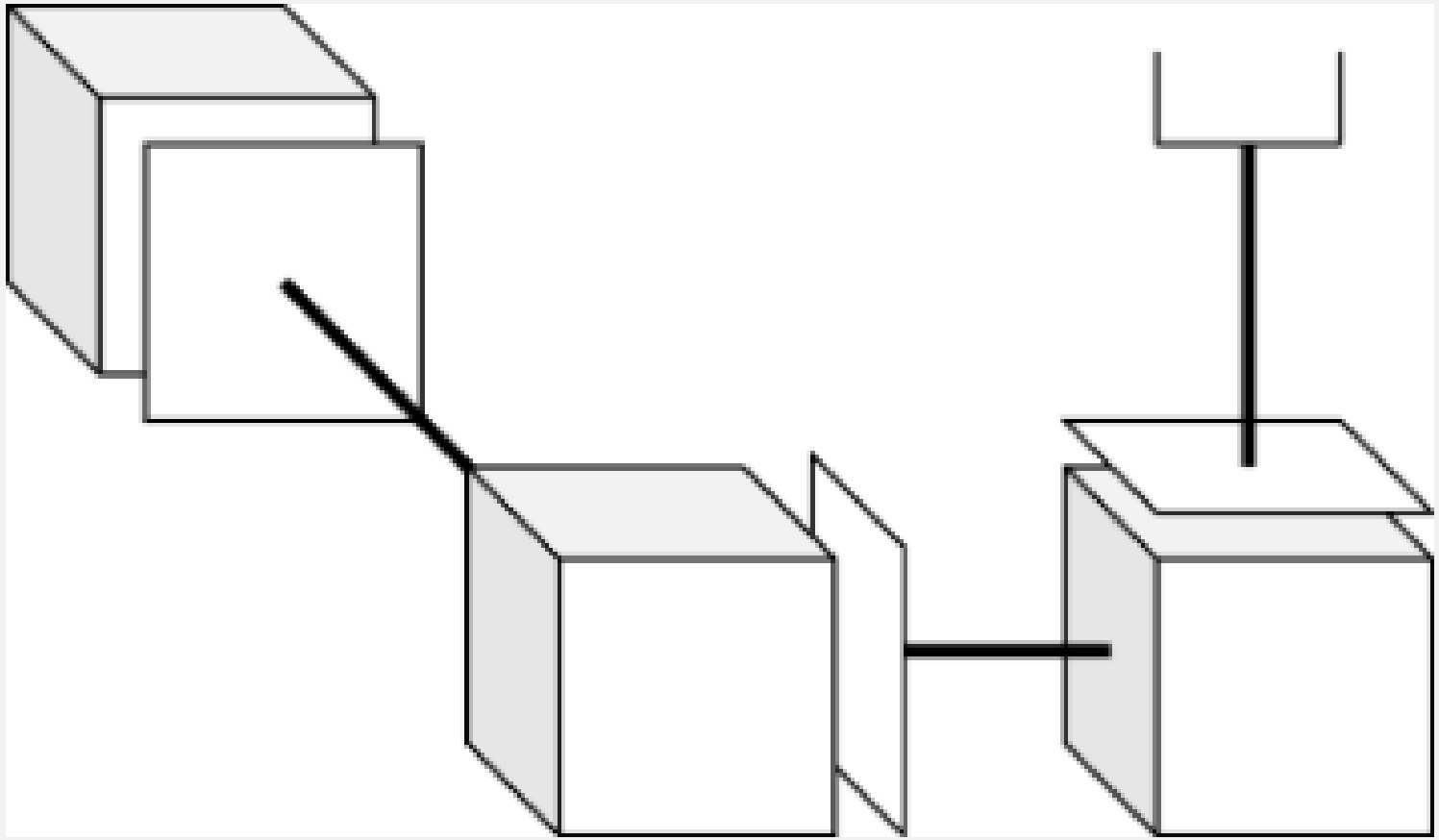
Select one alternative:

- Cartesian manipulator
- SCARA manipulator
- PPP manipulator
- Elbow manipulator

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Manipulator 2

A manipulator of which type is displayed in the following image?

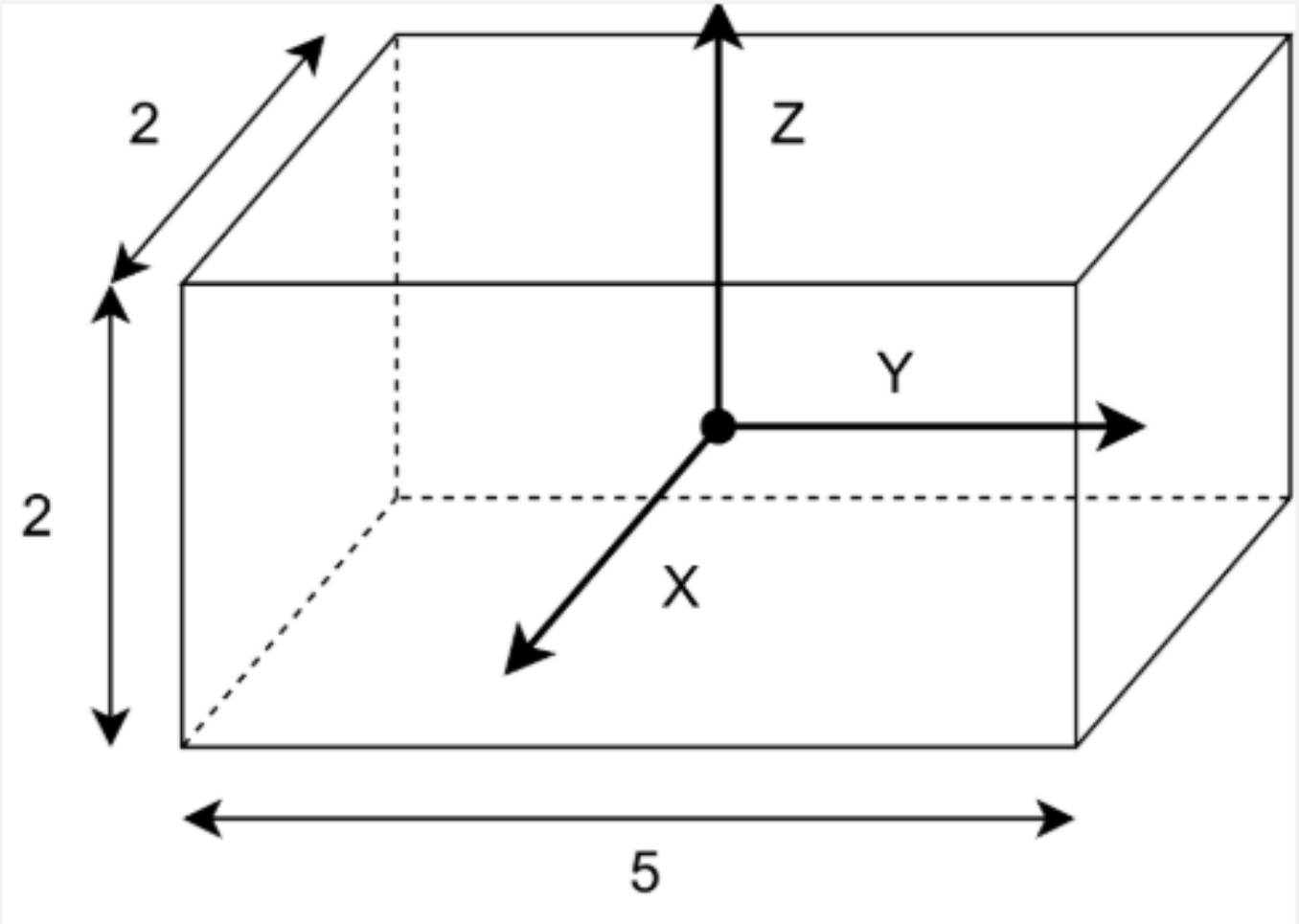


Select one alternative:

- PPR manipulator
- Spherical manipulator
- Cartesian manipulator
- Cylindrical manipulator

3 **Inertia calculation**

In Dynamics the Inertia (I) of an object can be expressed as a matrix. Given the box and the coordinate frame below:



What is the formula for calculating I_{xy}?

$$I_{xy} = -\int_{-1}^{1}\int_{-2.5}^{2.5}\int_{-1}^{1} xy + yz \; P(x,y,z)\, dx\, dy\, dz$$

$$I_{xy} = -\int_{-1}^{1}\int_{-2.5}^{2.5}\int_{-1}^{1} xy \; P(x,y,z)\, dx\, dy\, dz$$

$$I_{xy} = -\int_{-1}^{1}\int_{-2.5}^{2.5}\int_{-1}^{1} \left(z^2(x+y)\right) P(x,y,z)\, dx\, dy\, dz$$

$$I_{xy} = -\int_{-1}^{1}\int_{-2.5}^{2.5}\int_{-1}^{1} x^2 + y^2 \; P(x,y,z)\, dx\, dy\, dz$$

$\rho(x,y,z)$ is the density

$$I_{xx} = \iiint (y^2 + z^2)\rho(x,y,z)\,dx\,dy\,dz$$
$$I_{yy} = \iiint (x^2 + z^2)\rho(x,y,z)\,dx\,dy\,dz$$
$$I_{zz} = \iiint (x^2 + y^2)\rho(x,y,z)\,dx\,dy\,dz$$

} principal moments of inertia

$$I_{xy} = I_{yx} = -\iiint xy\,\rho(x,y,z)\,dx\,dy\,dz$$
$$I_{xz} = I_{zx} = -\iiint xz\rho(x,y,z)\,dx\,dy\,dz$$
$$I_{yz} = I_{zy} = -\iiint yz\rho(x,y,z)\,dx\,dy\,dz$$

} cross products of inertia

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Dynamics Coriolis

The general dynamics of a system can be expressed by the following equation:

$$\tau = D(q)\ddot{q} + C(q,\dot{q})\dot{q} + g(q)$$

Given the following Dynamics:

$$\tau = \begin{bmatrix} m_1 L_1^2 \ddot{q}_2 - m_2 L_2^2 s_2 \ddot{q}_1 - m_2 L_1 c_1 s_2 \dot{q}_1 + \frac{1}{2} m_1 g L_1 s_2 \\ m_2 L_1 c_2 \ddot{q}_2 + m_2 L_1^2 L_2^2 c_2 \dot{q}_1 \dot{q}_2 \end{bmatrix}$$

Which expression(s) would describe the **Coriolis and Centrefugal forces** acting on the system?

Select one alternative:

$$\begin{bmatrix} 0 & -m_2 L_1 S_2 C_1 \\ 0 & m_2 L_1^2 L_2^2 C_2 \dot{q}_1 \end{bmatrix} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix}$$

$$\begin{bmatrix} m_2 L_2^2 S_2 & -m_1 L_1^2 \\ 0 & m_2 C_2 L_1 \end{bmatrix} \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix}$$

$$\begin{bmatrix} m_2 L_2^2 S_2 & 0 \\ -m_1 L_1^2 & m_2 L_1 C_2 \end{bmatrix} \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix}$$

$$\begin{bmatrix} -m_2 L_1 C_1 S_2 & 0 \\ m_2 L_1^2 L_2^2 C_2 \dot{q}_2 & 0 \end{bmatrix} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix}$$

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Dynamics Inertial

The general dynamics of a system can be expressed by the following equation:

$$\tau = D(q)\ddot{q} + C(q,\dot{q})\dot{q} + g(q)$$

Given the following Dynamics:

$$\tau = \begin{bmatrix} m_1 L_1^2 \ddot{q}_2 - m_2 L_2^2 s_2 \ddot{q}_1 - m_2 L_1 c_1 s_2 \dot{q}_1 + \frac{1}{2} m_1 g L_1 s_2 \\ m_2 L_1 c_2 \ddot{q}_2 + m_2 L_1^2 L_2^2 c_2 \dot{q}_1 \dot{q}_2 \end{bmatrix}$$

Which expression(s) would describe the **Inertia forces** acting on the system?

Select one alternative:

$$\begin{bmatrix} 0 & -m_2 L_1 S_2 C_1 \\ 0 & m_2 L_1^2 L_2^2 C_2 \dot{q}_1 \end{bmatrix} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix}$$

$$\begin{bmatrix} -m_2 L_2^2 S_2 & m_1 L_1^2 \\ 0 & m_2 C_2 L_1 \end{bmatrix} \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix}$$

$$\begin{bmatrix} m_2 L_2^2 S_2 & 0 \\ -m_1 L_1^2 & m_2 L_1 C_2 \end{bmatrix} \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix}$$

$$\begin{bmatrix} -m_2 L_1 C_1 S_2 & 0 \\ m_2 L_1^2 L_2^2 C_2 \dot{q}_2 & 0 \end{bmatrix} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix}$$

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Control theory 1

Given a PI-controller with the following parameters: $K_p = 200$, $K_i = 20$.
After a time of t seconds, the integral sums up to 30.
The next call to the controller happens 0.25 seconds later. During this call the following data are sent to the controller: $q_{desired} = 2$, $q_{current} = 1.25$, $\Delta t = 0.25$, $\dot{q} = 0.05$

What will the output of the controller be? u(t+0.25): [ ] .

Attaching sketches to this question?
Use the following code:

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$$u(t) = K_p e(t) + K_i \int_0^t e(t')dt'$$

$$\int_0^t e(t')\,dt = 30 \qquad e(t) = q_d - q(t)$$

$$u(t+0{,}25) = 200(0{,}75) + 20\left(30 + \int_t^{t+0{,}25} (0{,}75)\,dt'\right)$$

$$= 150 + 20(30 + 0{,}25 \cdot 0{,}75)$$

$$= 150 + 20(30{,}1875)$$

$$\approx \underline{\underline{754}}$$

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Reality Gap

a) Why is "reality gap" a problem?

b) Why do we simulate robots?

Fill in your answer here

a) Why reality gap is a problem:

- real-world environments are complex difficult to model accurately in simulations and discrepancies between the real-world and the simulation can cause the robot to behave differently in a real world environment than in simulation.

- errors/discrepancies in simulation can be exploited by the AI and thus cause unexpected behavior in reality

b) Why we simulate robots:

- to avoid damaging physical robots
- safety - can avoid dangerous situations
- cheaper because we don't have to develop physical prototypes or spend a lot of time setting up physical experiments
- more effective in terms of ability to test out different algorithms/designs quickly.

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ROS 1

Your responses in text fields are saved automatically

What is a ROS node?

Fill in your answer here

ROS node:

- Code with a specific purpose in your system
- Can for example be a camera that publishes images or path planning or something like this
- Each node serves a purpose and in a larger system there are typically multiple nodes that address different tasks in the system and can communicate with each other through topics or services.

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ROS 2

Your responses in text fields are saved automatically

Why do we have different ROS-topics and ROS-messages?

Fill in your answer here

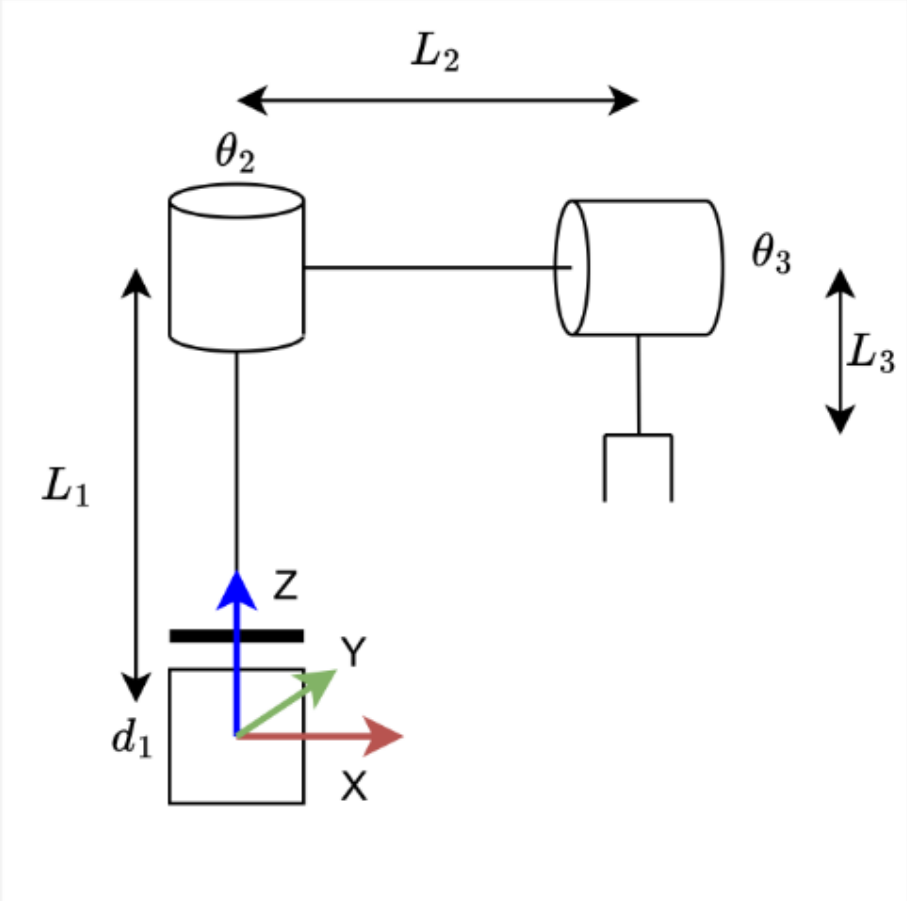
Why do we have different ROS topics and messages?

- The topics work as communication channels and we need different ones based on the information that should be communicated on the channel. The point is that each topic is dedicated to a specific task and thus it is known by the nodes that publish and subscribe to the topics what kind of information is shared.

- We need different messages because the messages contain different data that can be structured differently. Naturally, data such as text, numbers or pictures aren't represented in the same way and we need different message types with unique structure and composition for different data.

Kinematics

10 **Kinematics**



In this exercise you can answer with digital hand drawing. Use the handed out sketch sheets. See instructions on filling out the sketch sheets in the link below the task bar.

A) Draw the workspace

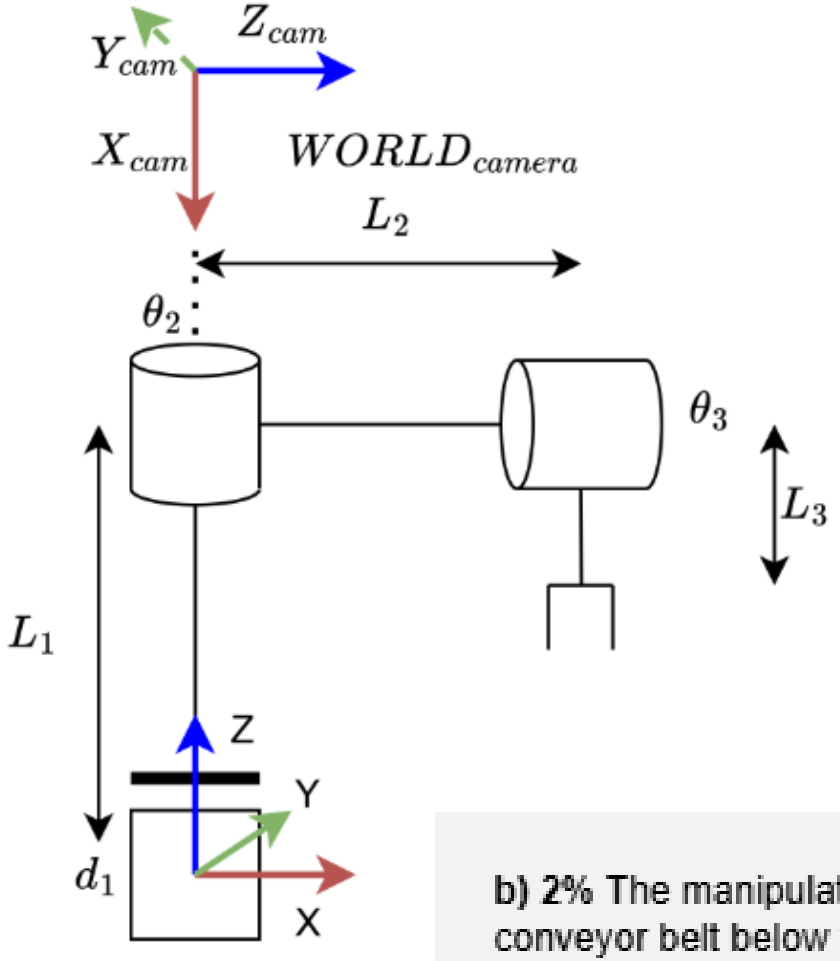
B) Assign coordinate frames + DH-table

C) Forward Kinematics

D) Inverse kinematics

E) Jacobian

Position World Frame

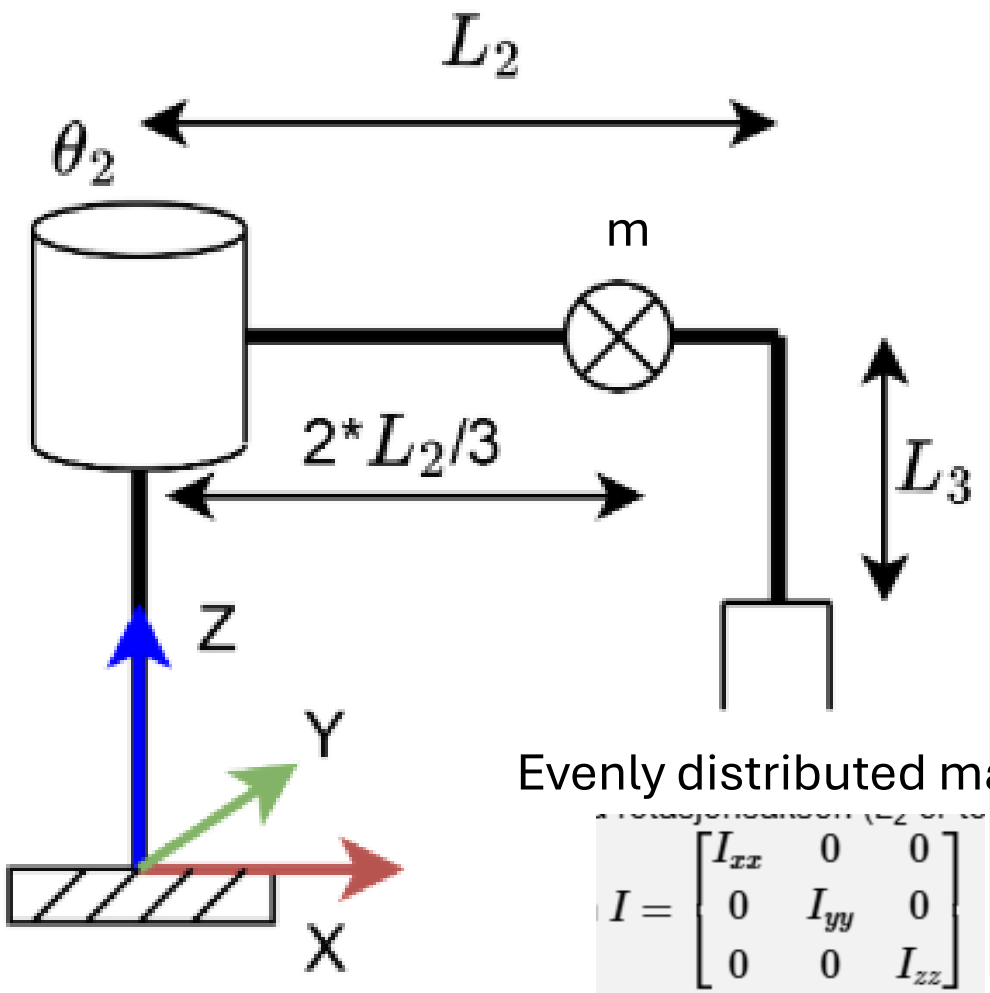


A) Position of tooltip in world frame

b) 2% The manipulator above has been tasked to work in a assembly-cell. The parts to assemble will come on a conveyor belt below the robot. The parts will have a **random orientation**, and the task is to mount the parts in a given **position** and **orientation**.
What challenges would the robot meet, and what types of modifications would we need to do to the robot so it can complete its task?

Since the parts come with a random orientation, the robot will not be able to grasp the objects since it does not have a wrist. Now it can only grab objects if they come on a specific orientation, so to complete the task, a spherical wrist (3 DOF) or some extra degrees of freedom needs to be added so that it is able to grab objects in any orientation.

Dynamics



A) Find Kinetic and Potential energy

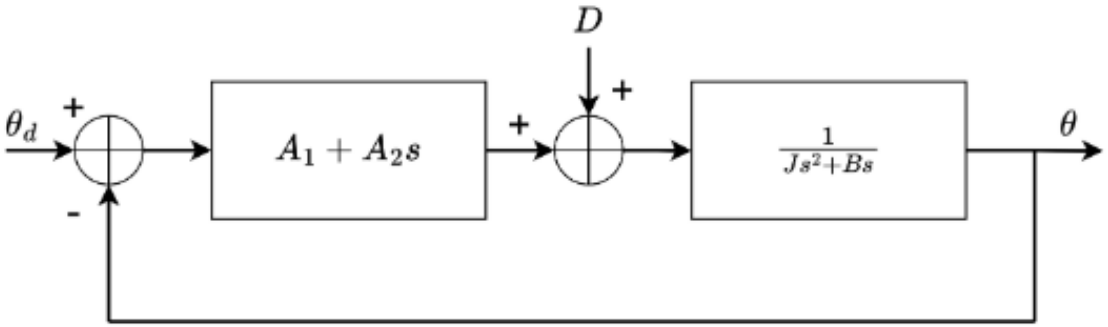
B) Assemble the Langrangian

C) Show how you can find the systems Kinetic and potential energy if we add back the prismatic joint 1, but still with joint 3 rigid (removed)

Evenly distributed mass with inertia

$$I = \begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}$$

Control theory



The equation for a system in the time domain follows the equation

$$\tau = J\ddot{\theta}(t) + B\dot{\theta} + D$$

A) Block design with basic blocks

B) Controller in drawing?

C) Transfer function H(s)

D) Step refernce and constant disturbance are given. Find steady state error by using the final value theorem

Step reference

$$\theta_d(s) = \frac{\psi}{s}$$

Constant disturbance

$$D = \frac{d}{s}.$$