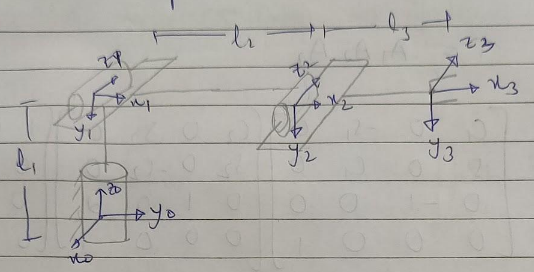
ME639: Midsem

Task 1.

Task 1

PUMA Manipulator



The DH parameters are as follows:-

Link	a	α	d	θ
1	0	-90	l_1	*
2	l_2	0	0	*
3	l_3	0	0	*

* ⇒ Variable

$$T = A_1 A_2 A_3$$

$$= \begin{bmatrix} C\theta_1 & 0 & -S\theta_1 & 0 \\ S\theta_1 & 0 & C\theta_1 & 0 \\ 0 & -1 & 0 & l_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C\theta_2 & -S\theta_2 & 0 & l_2 C\theta_2 \\ S\theta_2 & C\theta_2 & 0 & l_2 S\theta_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C\theta_3 & -S\theta_3 & 0 & l_3 C\theta_3 \\ S\theta_3 & C\theta_3 & 0 & l_3 S\theta_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T = \begin{bmatrix} C\theta_1 C\theta_{23} & -C\theta_1 S\theta_{23} & -S\theta_1 & l_3 C\theta_1 C\theta_{23} + l_2 C\theta_1 C\theta_2 \\ S\theta_2 C\theta_{23} & -S\theta_1 S\theta_{23} & C\theta_1 & l_3 S\theta_1 C\theta_{23} + l_2 C\theta_2 S\theta_1 \\ -S\theta_{23} & -C\theta_{23} & 0 & -S\theta_2 l_3 C\theta_3 - l_3 S\theta_3 C\theta_2 + l_1 - l_2 S\theta_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

So,
$$p_x = l_2 C\theta_1 C\theta_2 + l_3 C\theta_1 C\theta_{23}$$
$$p_y = l_2 C\theta_2 S\theta_1 + l_3 S\theta_1 C\theta_{23}$$
$$p_z = -l_3 S\theta_{23} + l_1 - l_2 S\theta_2$$

$$\theta_1 = \text{atan}\left[\frac{y}{x}\right]$$

$$\theta_2 = \text{atan}\left[\frac{\sin\alpha\cos\beta + \cos\alpha\sin\beta}{\cos\alpha\cos\beta - \sin\alpha\sin\beta}\right]$$

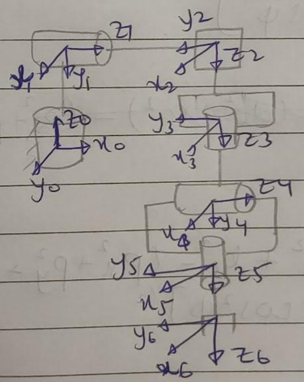
$$\theta_3 = \text{atan}\left[\frac{\sin\phi}{\cos\phi}\right]$$

~~Here,~~ $\cancel{\cos\phi = [a_2^2 + (a_4^2 + a_3^2) - (p_x^2 + p_y^2 + p_z^2)]/2l_1l_2}$
$\sin\phi$

Here, $\cos\phi = [l_2^2 + l_3^2 - (p_x^2 + p_y^2 + p_z^2)]/2l_1l_2$
$\sin\phi = [1 - \cos^2\phi]^{1/2}$

e)

e) Stanford Manipulator with Spherical wrist



For A,

We have

$$[O_x, O_y, O_z] = [0.45, 0.075, 0.1]$$

Also, wrist centre coordinates

$$[x_c, y_c, z_c] = [0.45, 0.075, 0.15]$$

We know

$$O_c = O - d_6 R \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} O_{x_c} \\ O_{y_c} \\ O_{z_c} \end{bmatrix} = \begin{bmatrix} O_x \\ O_y \\ O_z \end{bmatrix} - R_3^0 R_6^3 \begin{bmatrix} 0 \\ 0 \\ 0.05 \end{bmatrix}$$

$$R_3^0 R_6^3 \begin{bmatrix} 0 \\ 0 \\ 0.05 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0.05 \end{bmatrix}$$

$$R_6^3 \begin{bmatrix} 0 \\ 0 \\ 0.05 \end{bmatrix} = (R_3^0)^{-1} \begin{bmatrix} 0 \\ 0 \\ 0.05 \end{bmatrix}$$

Task 2.
Consider the pill picking robot desired by Timetooth Technologies. Their requirement is to have a preferably one-DOF gripper in a compact form factor (since it has to fit within a small cup) and be able to pick up a single pill lying in the cup in any orientation. A vacuum-based gripper is not desired.
a. Comment on whether you think a hard gripper or a compliant/soft gripper will be more suitable for this task. Please include a 4-6 sentence rationale for your preference. Even if you do not have a very precise reason, you could still include hypotheses in your arguments. Submit your answer in a PDF file format.

Although a hard gripper would suffice for a simplified version of the problem, I believe using a soft gripper would be more effective. With the soft robot, it would be easier to generalize the robot for all kinds of pills with different shapes and sizes. The grippers could be temporarily customized based on the shape and size of the pill making it easier to pick up just one pill at a time. Additionally, a soft gripper could also make it easier to enter the cup and pick up the pill. The shape of the soft gripper could be adjusted easily so that it can fit in cups of different shapes held in various orientations. Also, a camera tracking the gripper would be easily fit in a soft gripper.

b. Briefly review 'flexible mechanisms', 'soft robotic grippers', 'universal grippers', 'paper grippers' and 'origami robots' from information available on the web and comment on whether any of the ideas you explored seem suitable for this application. Include web links (either videos or papers) of any specific grippers that you felt might be worth considering and may serve as a good reference. Submit your answer in Word/ text (less preferred) format or in PDF file format (with preferably clickable links).

Soft Robotics' octopus-inspired robots industrial grippers
This could be a possible solution to the pill-picking problem. Since it is flexible and versatile, it would be easier for this kind of gripper to enter the cup and pick up a single pill. It could also be more easily generalized for different shapes and sizes of pills. Additionally, since it is a soft gripper, the chances of the pill crushing under its force would be unlikely.

Universal Gripper: Grabbing, Drawing, & Pouring
Universal grippers use granular material that engulfs the target object followed by the application of vacuum. While this is useful when the objects needed to be gripped are varied, it is hard for this gripper to pick up a single pill from a cup.

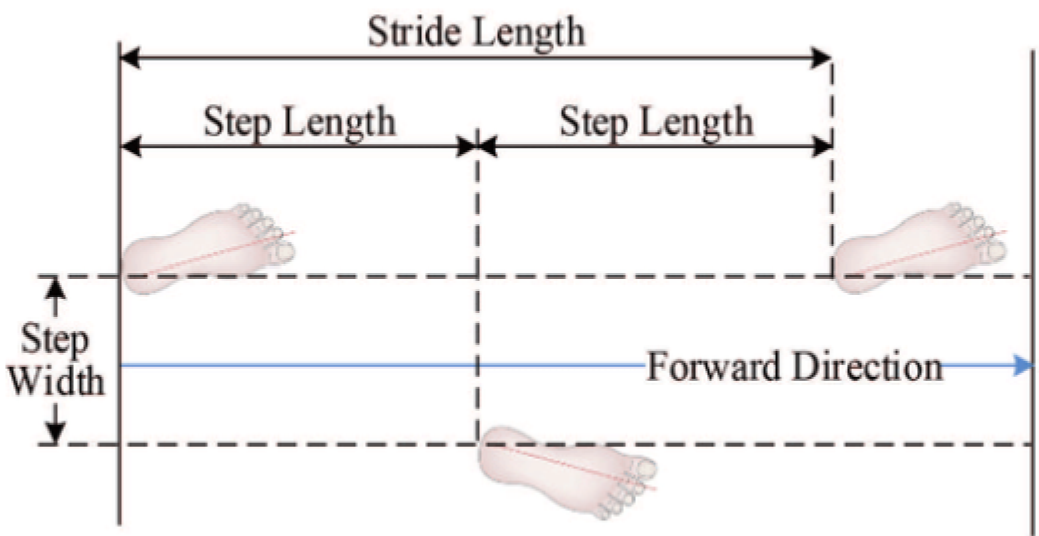
This Robot's Soft Gripper Was Inspired By Japanese Kirigami
This Kirigami style gripper could be seen as a potential design. Although the task of picking up a single pill would be hard to manifest. But due to its compactness and relative flexibility, it could serve as a good option. It also uses relatively cheap materials and so multiple grippers for different pill types could be manufactured.

Task 3.
Consider the exoskeleton scruffing problem from TimeTooth Technologies.
Consider only one side of the exoskeleton and consider it to be a planar 2R elbow manipulator.

a. First, pick reasonable link lengths by searching for (or measuring your own) hip-to-knee distance as the first link and knee-to-ankle distance as the second link and state these values. Also read about gait trajectory, step height, and step length and explain what they are in 1-2 sentences each. Submit this in PDF format.

For an average male, the hip-to-knee distance is 46cm which gives the first link length. Now, the knee-to-ankle distance for an average male is 45cm which gives the second link length.
There are two major phases in a gait cycle, the stance phase and the swing phase. The stance phase which comprises 60% of the total gait cycle starts with

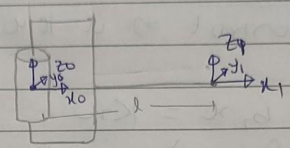
the foot touching the ground and ends with the foot leaving the ground. The rest 40% comes in the swing phase. Some important gait parameters are step length, step height, stride length, etc. Step length is the distance between the rear ends of two successive footprints measured along the line of progression. Step height is the maximum height the foot reaches before its descent towards the ground.



Task 4:

Task 4

a)



Link	a	α	d	θ
1	0	0	l	θ_1^*

Here, θ_1 is variable.

b) We already have

$$\tau = ml^2 \frac{d^2q}{dt^2} + mgl\sin(q)$$

Now from inverse kinematics, we have

$$F_y l\cos(q) - F_x l\sin(q) = \tau$$

Substituting
$$F_x = K_x(x - x_0)$$
$$= K_x(l\cos(q) - x_0)$$

$$F_y = K_y(l\sin(q) - y_0)$$

$$\tau_s = K_y(l\sin q - y_0)\, l\cos(q) - K_x(l\cos q - x_0)\, l\sin q$$

$$\tau_{total} = \tau + \tau_s$$

$$\tau_{total} = ml^2\frac{d^2q}{dt^2} + mgl s_q + K_y(l s_q - y_0) l c_q + K_x(l c_q - x_0) l s_q$$

Task 5:
In the DH convention are all joint axes always aligned with the respective z-axis?

Yes. The axis of rotation and linear prismatic motion is taken as the corresponding z-axis for that coordinate system.

Task 6.
In the DH convention, are the origins of all the coordinate frames always at the centres of the joints?

No. The origins of the coordinate frames could be anywhere in free space.

Task 7.
Is it true that a homogeneous transformation consists of both a rotation and a translation?

For the most general case, homogeneous transformations consist of both rotation and translation. However, for special cases, it could consist of either of the two.

Task 8.
For a sequence of rotations performed one after the other, can the rotation matrices for each individual rotation be multiplied together to form the overall rotation matrix (capturing the sequence of rotations)?

Yes. For the composition of rotations performed one after the other about the current axis, the composite rotation matrix can be written as:

$$R_0^n = R_0^1 R_1^2 \qquad R_{n-1}^n$$

If the rotations are performed about a fixed axis, then the order of multiplication reverses. The composite matrix can be written as:

$$R_0^n = R_{n-1}^n R_{n-2}^{n-1} \qquad R_0^1$$

Task 9.
Is a composite rotation matrix consisting of a sequence of several rotations still an orthogonal matrix with the determinant equal to 1?

Yes. We know that the rotation matrix is orthogonal with the determinant equal to one. Since the composite matrix is just the multiplication of such matrices, it will also be orthogonal in nature with its determinant equal to one.