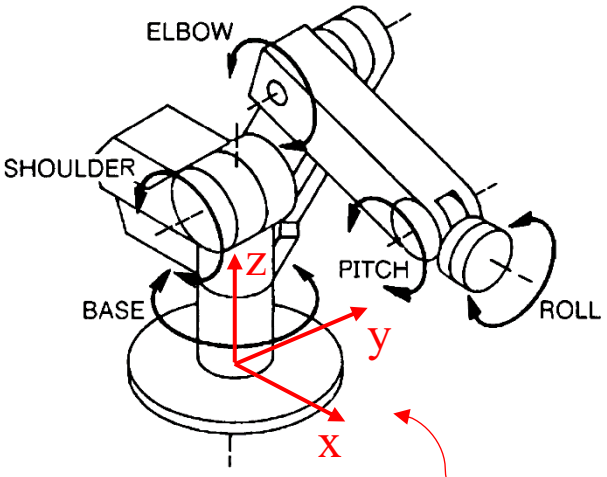
2023 Robotics Assignment II
Forward Kinematics and Inverse Kinematics

Due: 2023/10/23 13:00 pm (GMT+8)

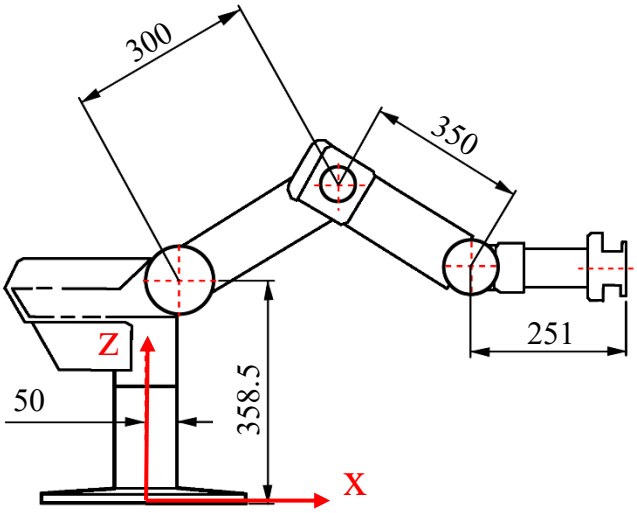
Consider the ER-7 robot arm shown in the following figures, please answer the following questions and provide your basic idea, process (key steps showing it can derive the answer), and the answer.

Note: Feel free to use a calculator or write a computer program to help you solve the problems.

Unit: mm

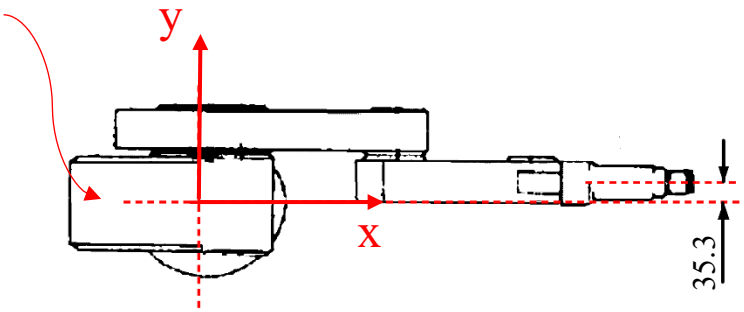


Oblique Drawing



Lateral View

Base Coordinate



Top View

PART A (25%)

I. According to ER-7 arm, draw the link coordinate diagram using D-H convention in Craig version (lecture 3 slides page 38). **(10%)**

II. Find the kinematics parameters of ER-7 and fill the table below: **(15%)**

Joint	α_{i-1} (°)	a_{i-1} (mm)	d_i (mm)	θ_i
1				θ_1
2				θ_2
3				θ_3
4				θ_4
5				θ_5

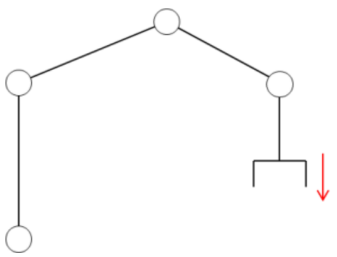
PART B (30%)

Derive transformation matrices for each consecutive link, and also the transformation matrices ${}^{base}_{5}T$(from frame 5 to frame base).

Note: This should be revised to list all the transformation matrix, i.e.
${}^{base}_{1}T,\ {}^{1}_{2}T,\ {}^{2}_{3}T,\ {}^{3}_{4}T,\ {}^{4}_{5}T,\ {}^{base}_{5}T$

PART C (45%)

I. **Derive the inverse kinematics** for ER-7. Given the target pose of the gripper tip $(x, y, z, \phi, \theta, \psi)$ with respect to the base coordinate, calculate $(\theta_1, \theta_2, \theta_3, \theta_4, \theta_5)$. For the transformation from the base to the gripper tip, please refer to Inverse Kinematic slides. Let's assume the target is reachable in elbow-up configuration, and that the gripper tip pose is **always vertically downward**. **(30%)**



II. Based on the previous question, please calculate $(\theta_1, \theta_2, \theta_3, \theta_4, \theta_5)$ with the following target poses (poses of the last frame relative to the base coordinate). The translation parameters (x, y, z) are in millimeter, and the rotation parameters (ϕ, θ, ψ) are Euler representation (ZYX Euler Angle) in radian. **(15%)**

A. $(x, y, z, \phi, \theta, \psi) = (600,100,0, \frac{\pi}{4}, 0, \pi)$

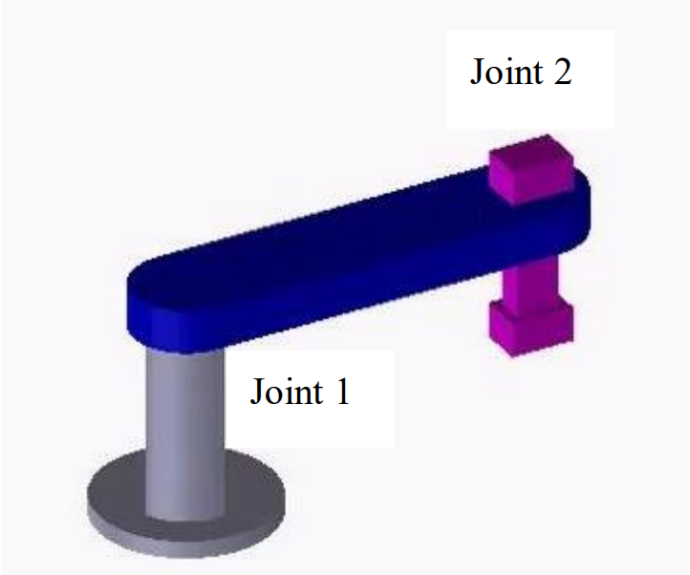
B. $(x, y, z, \phi, \theta, \psi) = \left(600,100,50, \frac{\pi}{4}, 0, \pi\right)$

III. For the following target pose, the gripper tip is vertically upward. Is this pose reachable? Derive the robot joint configuration $(\theta_1, \theta_2, \theta_3, \theta_4, \theta_5)$ if it is reachable, or briefly justify if it is not. **(10% bonus)**

$$(x, y, z, \phi, \theta, \psi) = (600,100,0, -\frac{\pi}{4}, 0, 0)$$

PART D (5% bonus) mission

Consider the following robot arm which is consist of a revolute joint and prismatic joint:



I. Find the DH representation the same as Part A.I (6%)

II. For all DH parameters ($\boldsymbol{\alpha_{i-1}}$, $\boldsymbol{a_{i-1}}$, $\boldsymbol{d_i}$, $\boldsymbol{\theta_i}$), which two parameters are actuator joint (varying parameters)? **(4%)**

Submission

Please convert your report into a **PDF file, submit to the NTU COOL.**
Name your PDF file as <STUDENT_ID>_HW2.pdf. For example, R12345678_HW2.pdf
Extra label due to re-submission on NTU COOL is acceptable.