UNIVERSITY COLLEGE TATI

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UNIVERSITY COLLEGE TATI (UCTATI)

FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BMT 4023
COURSE	: INDUSTRIAL ROBOTIC AND APPLICATION
SEMESTER/SESSION	: 2-2024/2025
DURATION	: 3 HOURS

Instructions:

1. This booklet contains 4 questions. Answer **all** questions.

2. All answers should be written in the answer booklet.

3. Write legibly and draw sketches wherever required.

4. If in doubt, raise your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

THIS BOOKLET CONTAINS <u>6</u> PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

A robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum of the mechanism or may be part of a more complex robot.

a) Regarding the robotic arm shown in Figure 1, identify the links and joints of the robotic arm. *(You need to sketch for each link and joint of the robot).*

(12 marks)

b) Describe **four** (4) types of robot joints in industrial robotics application.

(8 marks)

c) Describe **five** (5) types of safeguard device which are used in industrial robotic work cell.
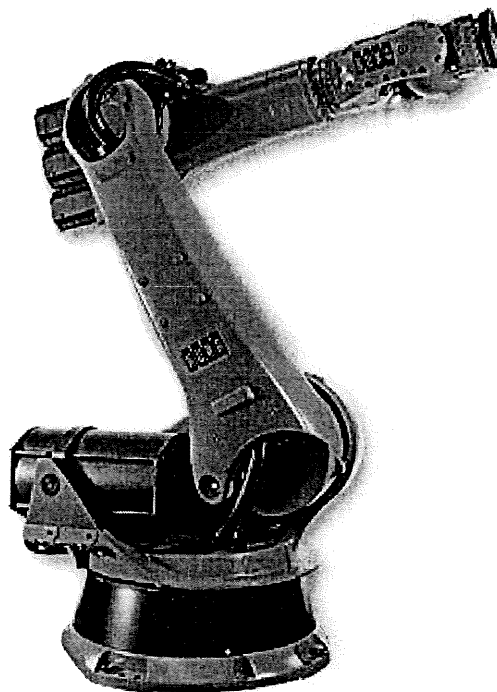
(5 marks)

Figure 1: KUKA Robot

QUESTION 2

There are two composite transformations: pre-multiplication and post-multiplication. **Produce** the **calculation** of the composite transformation matrix for the following problems. You may refer formula in attachment section:

a) Assume the point P $(3\ 2\ 5)^T$ is attached to a frame $x0y0z0$, but all relative to the current moving frame, as listed below:

- A rotation of 45° about the $z1$ axis
- Followed by a translation of (3,1,1) along $x1y1z1$ axis
- Followed by a rotation of 45° about the $y1$ axis
- Followed by a rotation of 90° about the $x1$ axis

(12 marks)

b) A point P with coordinate $(1\ 3\ 6)^T$ is attached to a frame $x1y1z1$ and is subjected to the transformations described below:

- A rotation of 45° about the $y0$ axis
- Followed Translation of (1, 1, -3) along $x0y0z0$ axis
- Followed by Rotation of 45° about the $z0$ axis
- Followed by a rotation of 90° about the $x0$ axis

(12 marks)

c) State which one of part a) or part b) is post-multiplication.

(1 mark)

QUESTION 3

Figure 2 shows the real picture of Motoman HP-20 industrial robot and Table 1 shows its joint parameter after the process of finding DH parameter.

a) By using the relationship between adjacent frames given in attachment, obtain the equation of relationships for every joint if the θ value for joint 1 to 3 is set to 70 degrees and joint 4 to 6 is set to 20 degrees.

(18 marks)
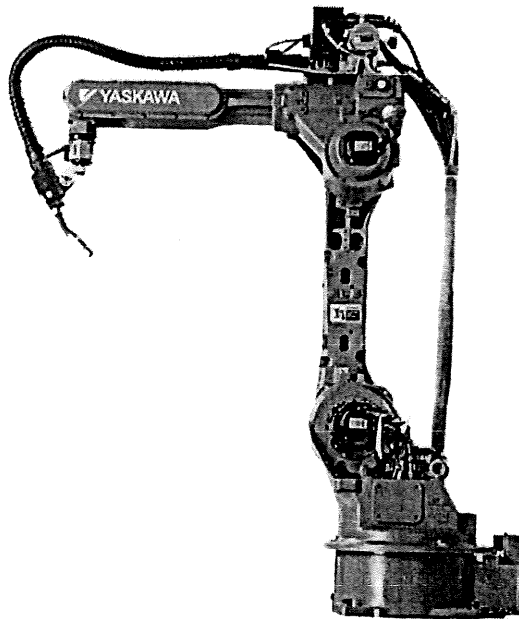
b) Calculate the forward kinematics solution.

(7 marks)

Figure 2: Yaskawa Motoman HP-20 robot

Table 1: Joint parameter of Motoman HP-20 robot

Joint	$\theta(°)$	$d\ (mm)$	$\alpha(°)$	$a\ (mm)$	θ range($°$)
1	θ_1	0	0	0	-180~180
2	θ_2	0	90	$a_2 = 150$	-110~155
3	θ_3	0	0	$a_3 = 760$	-165~255
4	θ_4	$d_4 = 795$	90	$a_4 = 140$	-200~200
5	θ_5	0	-90	0	-50~230
6	θ_6	0	90	0	-360~360

QUESTION 4

Assume that a motionless single link robot manipulator with a rotary joint will be smoothly moved its initial angular position $\theta_o(0) = 5°$ to the final angular position $\theta_i(3) = 90°$ with zero initial velocity and zero final velocity. Given $t_0 = 0$ to the final time $t_f = 3$ seconds. Let the cubic polynomial $\theta(t)$ be of the form:

$$\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3$$

a)   Calculate the trajectory of a single manipulator.

(7 marks)

b)   Determine the value of position, velocity, and acceleration for each time from 0.5s, 1.0s, 1.5s, 2.0s, 2.5s.

(15 marks)

c)   Sketch the trajectory graph of position, velocity, and acceleration to realize this motion in 3 seconds.

(3 marks)

--End of question--

Attachment

Homogeneous Rotation Matrix

$$T_{x,\theta} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad T_{y,\theta} = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T_{z,\theta} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The basic homogeneous
rotation matrices

Homogeneous Translation Matrix

$$T_{trans} = \begin{bmatrix} 1 & 0 & 0 & dx \\ 0 & 1 & 0 & dy \\ 0 & 0 & 1 & dz \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Formula of relationship between adjacent frames:

$$^{i-1}A_i = \begin{bmatrix} \cos\theta_i & -\cos\alpha_i\sin\theta_i & \sin\alpha_i\sin\theta_i & a_i\cos\theta_i \\ \sin\theta_i & \cos\alpha_i\cos\theta_i & -\sin\alpha_i\cos\theta_i & a_i\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$