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UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE TATI (UCTATI)

FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BMT 4023
COURSE	: INDUSTRIAL ROBOTICS AND APPLICATION
SEMESTER/SESSION	: 1-2023/2024
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 6 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).*

(5 marks)

b) Describe **four** (4) comparisons between robot and human in industrial robotics application

(8 marks)

c) Describe **four** (4) configurations of industrial robotic and give **two** (2) each of their advantage and disadvantage.

(12 marks)

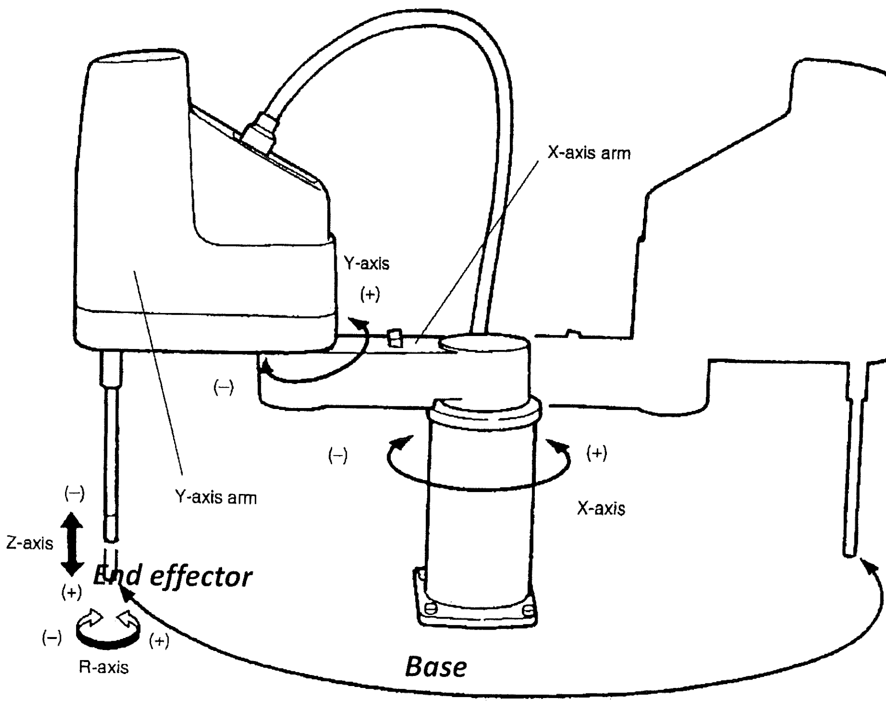

Figure 1: SCARA Robot

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 90° about the z1 axis
- Followed by a rotation of 90° about the y1 axis
- Then a translation of (3,4,4) along x1y1z1 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:

- Translation of (5, -1, 8) along x0y0z0 axis
- Followed by Rotation of 90° about the z0 axis
- Followed by a rotation of 90° about the y0 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 marks)

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 all joint is set to 35 degrees.

(18 marks)

b) Calculate the forward kinematics solution.

(7 marks)

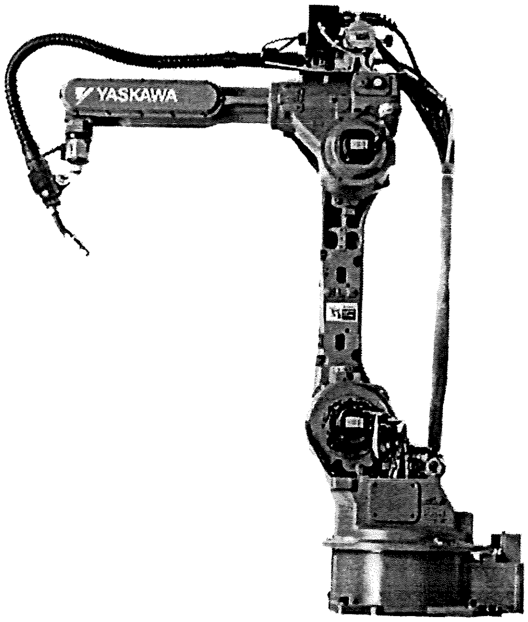

Figure 2: Yaskawa Motoman HP-20 robot

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 $\theta_o(0) = 10°$ to the final angular position $\theta_i(3) = 65°$ 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:

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