Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	INDUSTRIAL ROBOTICS
COURSE CODE	:	BND 43003
PROGRAMME CODE	:	BND
EXAMINATION DATE	:	JULY/ AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTIONS		1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.** 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

Q1 (a) Define the following terms used in industrial robotics.
(i) Revolute
(ii) Prismatic
(iii) Degrees of Freedom

(6 marks)

(b) Compare the advantages and disadvantages of robot application.

(8 marks)

(c) Robots can be classified according to the types of tasks, control, configuration, and mobility.
Define classification by task and mobility

(6 marks)

Q2 (a) A frame has been moved 4 units along the x-axis and 5 units along the y-axis of the reference frame. Determine the new location of the frame.

$$F = \begin{bmatrix} 0.7 & -0.4 & 0.8 & 5 \\ 0.9 & 0.9 & 0.9 & 3 \\ -0.7 & 0 & 0.6 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(3 marks)

(b) A point P= [7, 3, 2] ^{T}, which attached to a frame (n, o, a) relative to frame B, is subjected to the following transformation. Calculate the total transformation matrix:

(i) A rotation of 30° about the y-axis,
(ii) Followed by a rotation of 90° about the o-axis,
(iii) Followed by a translation of 4 units along the n-axis,

(6 marks)

(c) Suppose that a robot is made of a Cartesian and RPY combination of joints. Calculate the necessary RPY angles to achieve the following coordinates.

$$B = \begin{bmatrix} 0.354 & 0.674 & 0.649 & 4.33 \\ 0.505 & 0.722 & 0.475 & 2.5 \\ 0.788 & 0.160 & 0.595 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(8 marks)

(d) Calculate the inverse of the following transformation matrix:

$$F = \begin{bmatrix} 0.5 & 0 & 0.866 & 3 \\ 0.866 & 0 & 5 & 2 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(3 marks)

Q3 For the three-link planar arm with prismatic joint of **Figure Q3**:

(a) Assign the coordinate frames based on D-H representation.

(8 marks)

(b) Fill out the parameters table shown in **Table Q3(b).**

(8 marks)

(c) Write the ${}^{U}\boldsymbol{T}_{H}$ matrix in terms of the A matrices.

(4 marks)

Q4 (a) The Jacobian of a robot at a particular time is given below. Compute the linear and angular differential motions of the robot's hand frame for the given joint differential motions.

$$J = \begin{bmatrix} 2 & 0 & 0 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} D_\theta = \begin{bmatrix} 0 \\ 0.1 \\ -0.1 \\ 0 \\ 0 \\ 0.2 \end{bmatrix}$$

(2 marks)

(b) The last column of the forward kinematic equation of the simple revolute arm is:

$$\begin{bmatrix} P_x \\ P_y \\ P_z \\ 1 \end{bmatrix} = \begin{bmatrix} C_1(C_{234}a_4 + C_{23}a_3 + C_2a_2) \\ S1(C_{234}a_4 + C_{23}a_3 + C_2a_2) \\ S_{234}a_4 + S_{23}a_3 + S_2a_2 \\ 1 \end{bmatrix}$$

Calculate the Jacobian of P_x and P_y of above robot.

(9 marks)

(c) The last column of the forward kinematic equation of a simple revolute arm is:

$$A1 = \begin{bmatrix} C_1 & 0 & S_1 & 0 \\ S_1 & 0 & -C_1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad A2 = \begin{bmatrix} C_2 & -S_2 & 0 & C_2a_2 \\ S_2 & C_2 & 0 & S_2a_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A3 = \begin{bmatrix} C_3 & -S_3 & 0 & C_3a_3 \\ S_3 & C_3 & 0 & S_3a_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad A4 = \begin{bmatrix} C_4 & 0 & -S_4 & C_4a_4 \\ S_4 & 0 & C_4 & S_4a_4 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A5 = \begin{bmatrix} C_5 & 0 & S_5 & 0 \\ S_5 & 0 & -C_5 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad A6 = \begin{bmatrix} C_6 & -S_6 & 0 & 0 \\ S_6 & C_6 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Calculate the ${}^{T6}J_{24}$ element of the Jacobian for the above revolute arm robot.

(9 marks)

Q5 Derive the equations of motion for the two-degree-of-freedom system in **Figure Q5**.

(20 marks)

- **END OF QUESTION –**

FINAL EXAMINATION

SEMESTER/SESSION	:	SEM II/2022/2023	PROGRAMME CODE	:	BND
COURSE NAME	:	INDUSTRIAL ROBOTICS	COURSE CODE	:	BND 43003

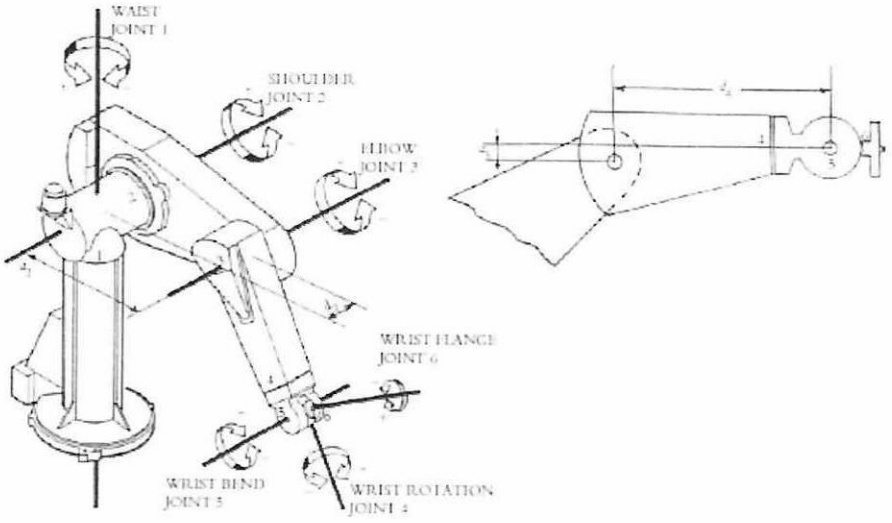

Figure Q3

	θ	D	a	α
0-1				
1-2				
2-3				
3-4				
4-5				
5-6				

Table Q3 (b)

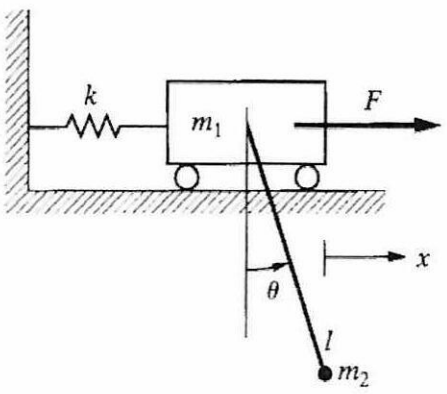

Figure Q5