Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	ROBOTIC SYSTEMS
COURSE CODE	:	BEJ 44203
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	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 **FOUR (4)** PAGES

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Q1 (a) State **TWO (2)** factors that might affect the repeatability and accuracy of a manipulator.

(2 marks)

(b) The corresponding arm parameters and the forward kinematics matrix for a spherical arm with two rotary joints and prismatic joints as follows:

$$H_0^3 = \begin{bmatrix} -S_1 & C_1C_2 & C_1S_2 & d_3C_1S_2 + d_2S_1 \\ C_1 & S_1C_2 & S_1S_2 & d_1S_1S_2 - d_2C_1 \\ 0 & S_2 & -C_2 & d_1 - d_3C_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(i) Derive the position vector of the tip of the arm.

(2 marks)

(ii) Obtain the solution of θ_1 and d_3.

(8 marks)

(c) **Figure Q1(c)** shows a three-link planar arm with three joints. Derive the Jacobian for the three-link arm. The homogenous transformation matrices are given as follows:

$$H_0^1 = \begin{bmatrix} C\theta_1 & 0 & S_1 & 0 \\ S\theta_1 & 0 & -C_1 & 0 \\ 0 & 1 & 0 & \alpha_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$H_1^2 = \begin{bmatrix} -S\theta_1 & 0 & C\theta_2 & \alpha_2C\theta_2 \\ C\theta_1 & 0 & S\theta_2 & \alpha_2S\theta_2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$H_0^3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & \alpha_3 + 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(13 marks)

Q2 (a) A single-link robot with a rotary joint is motionless at $\theta = -5^\circ$. It is desired to move the joint in a smooth manner to $\theta = 80^\circ$ in 4 seconds. The initial velocity and final velocity are zero. Design a cubic trajectory to accomplish this motion and bring the arm to the rest at the goal.

(13 marks)

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(b) Solve for the coefficients of two-segments of continuous velocity and acceleration spline with initial angle is $\theta_0 = 5°$. The via point is $\theta_v = 15°$, and the goal point is $\theta_g = 40°$. The designated trajectory should have zero initial velocity and zero final velocity. Each segment lasts 1.0 seconds.

The first cubic $(0 \leq t \leq 1)$ is

$$\theta(t) = a_{10} + a_{11}t + a_{12}t^2 + a_{13}t^3$$

and the second cubic $(1 \leq t \leq 2)$ is

$$\theta(t) = a_{20} + a_{21}(t-1) + a_{22}(t-1)^2 + a_{23}(t-1)^3$$

(12 marks)

Q3 Consider the point masses at distal ends of link of the following two-link manipulator as shown in **Figure Q3**. The link lengths are described by l_1 and l_2.

(a) Find the Cartesian coordinates of the point masses m_1 and m_2.

(5 marks)

(b) Calculate the velocities of the point masses m_1 and m_2.

(8 marks)

(c) Evaluate the differential equation of T_{θ_1} for the first link of the manipulator.

(12 marks)

Q4 (a) Identify the natural and artificial constraints for the task of closing a hinged door with manipulator. Make any reasonable assumptions needed and show your definition of {C} in sketch.

(18 marks)

(b) Discuss **ONE** example of the application of hybrid position/force controller in robot manipulator operation.

(7 marks)

-END OF QUESTIONS –

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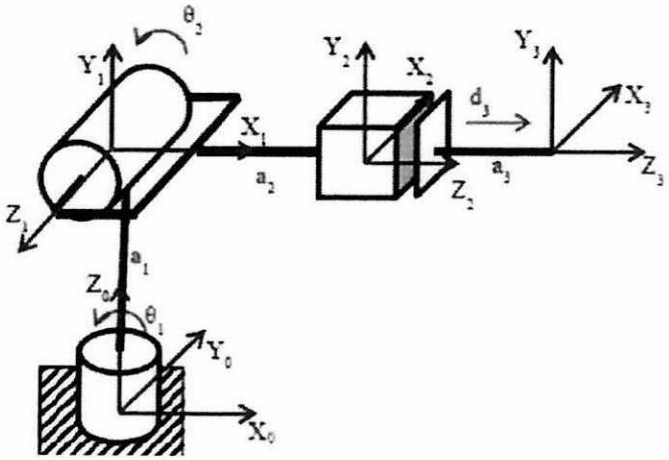

Figure Q1(c)

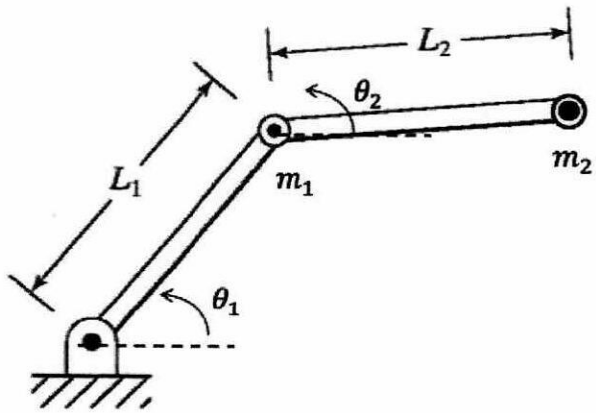

Figure Q3

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