The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX7303 Control of Robotic Manipulators**
Academic Year	: 2021/22
Date	: 03rd February 2023
Time	: 14:00 -17:00 hrs.
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Four (4)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (CBT).
6. Answers should be in clear handwriting.
7. Do not use Red colour pen.

Question 01

(a) Industrial robotic manipulators are widely used in the modern factory environment, especially as manufacturing support systems. What make an industrial robotic manipulator differ from other forms of automated devices or systems used in factory environment? Elaborate. *(04 Marks)*

(b) Briefly discuss the evolutionary stages in robotics, emphasizing on their characteristics, control capabilities and applications. *(12 Marks)*

(c) Explain the term 'degree of freedom' with respect to robotic manipulators. You may use a neatly drawn sketch to illustrate your answer. *(04 marks)*

Question 02

(a) State and elaborate on robot specifications with regard to;

(i) Speed

(ii) Precession of movement *(08 marks)*

(b) Why robot's accuracy is often considered as one-half of its control resolution? Explain. *(06 marks)*

(c) A robot's link is actuated by a geared stepper motor. The gear connected to the stepper motor has 15 teeth while the gear connected to the link of the robot has 60 teeth. The controller dives the motor at 1.50 per pulse. Determine its link resolution. *(06 marks)*

Question 03

A gripper attached to the end-effector of a robotic manipulator is to position and orient itself according to the frames as indicated in Figure 01 below.

Find the homogeneous transformation matrices ${}^{i-1}\mathbf{T}_i$ and ${}^{0}\mathbf{T}_i$ for $i = 1, 2, 3, 4$, and 5.

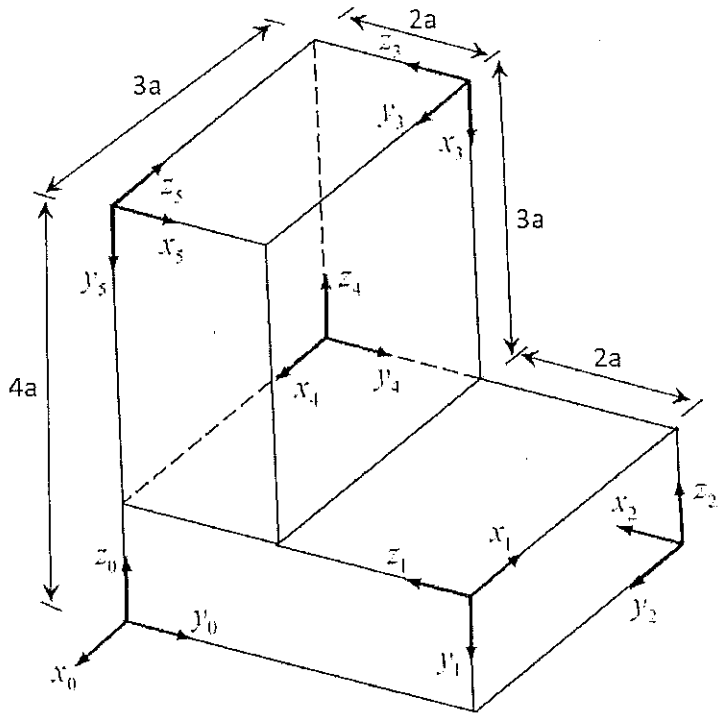

Figure 01

(20 marks)

Question 04

Cylindrical configuration type robotic manipulators are widely used in the industry due to its simplicity and ease of programming. For a typical cylindrical type robotic manipulator;

(i) Draw the kinematic diagram and assign frames according to the Denavit Hartenberg (DH) convention. *(06 marks)*

(ii) Create the DH parameter table and find the DH parameters, θ, α, r and d. *(06 marks)*

(iii) Using the values of parameters in the DH table find the homogeneous transformation of the end effector with respect to the base frame. *(08 marks)*

(Note: You may use the standard transformation matrix shown by equation 01 in order to find the homogenous transformation matrix)

$$ {}^{n-1}\mathbf{T}_n = \begin{bmatrix} C(\theta_n) & -S(\theta_n)C(\alpha_n) & S(\theta_n)S(\alpha_n) & r_n C(\theta_n) \\ S(\theta_n) & C(\theta_n)C(\alpha_n) & -C(\theta_n)S(\alpha_n) & r_n S(\theta_n) \\ 0 & S(\alpha_n) & C(\alpha_n) & d_n \\ 0 & 0 & 0 & 1 \end{bmatrix} \text{----(Equation 01)} $$

Question 05

(a) Why do inverse kinematic problems in relation to robotic manipulators give more than one solution? *(04 marks)*

(b) Figure 02 represents a kinematic diagram for a 2 degree of freedom manipulator. Find the inverse kinematic equations. (*You may use the geometrical approach in finding the solution.*)

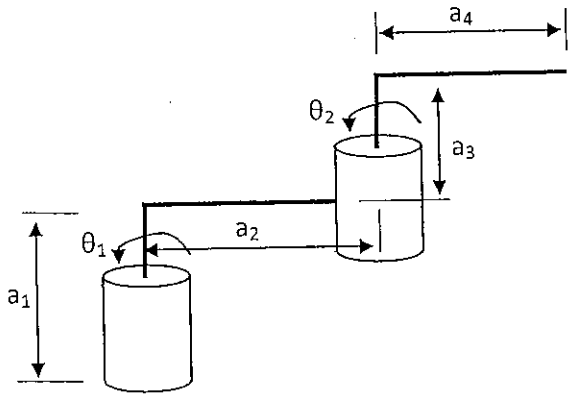

Figure 02

(16 marks)

Question 06

(a) What is the significance of the Jacobian matrix in relation to robotic manipulators? *(04 marks)*

(b) Using first principles obtain an expression for the Jacobian matrix for a spherical robotic manipulator. *(16 marks)*

Question 07

The dynamics of a simple manipulator can be found by a scalar function called the Lagrangian (L), which is the difference between the kinetic energy (K) and the potential energy (P) of the manipulator system. That is, L= K – P.

Figure 3 represents a simplified version of a two degree of freedom planar inverted manipulator. For the manipulator the joint variables are θ_1 and θ_2, link lengths are l_1 and l_2 and the masses are m_1 and m_2 respectively, which are located at end of each link.

Find the dynamic model (equations of motion) for the manipulator system represented by Figure 3 based on the Lagrangian. State any assumptions you make. *(20 marks)*

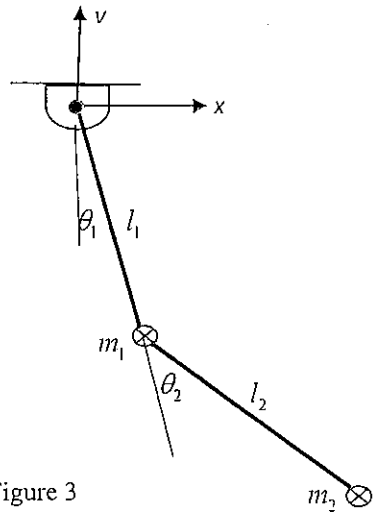

Figure 3

Question 08

(a) Using first principles solve for the coefficients of a cubic polynomial trajectory in joint space trajectory scheme. *(6 marks)*

(b) A particular joint of a manipulator is to move from an initial position of 200 to a final position of 800 in 4 seconds. Assuming that the joint starts and finishes at zero velocity, find the cubic polynomial that satisfies this motion. Also determine the position, velocity and acceleration of this joint at intervals of 1 second and plot these against time. *(14 marks)*