UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2022/2023 Academic Session

July / August 2023

EEE355 – Robotic & Automation

Duration : 2 hours

Please check that this examination paper consists of **FIVE (5)** pages of printed material including appendix before you begin the examination.

Instructions : This paper consists of **FOUR (4)** questions. Answer **ALL** questions.

...2/-

1. a) Define forward kinematics and inverse kinematic analysis with reference to an industrial robotic arm.

(20 marks)

b) Consider the arm shown in Figure 1.

i. Solve the forward kinematics problem, i.e. determine the ${}^0T_3$ transformation.

(40 marks)

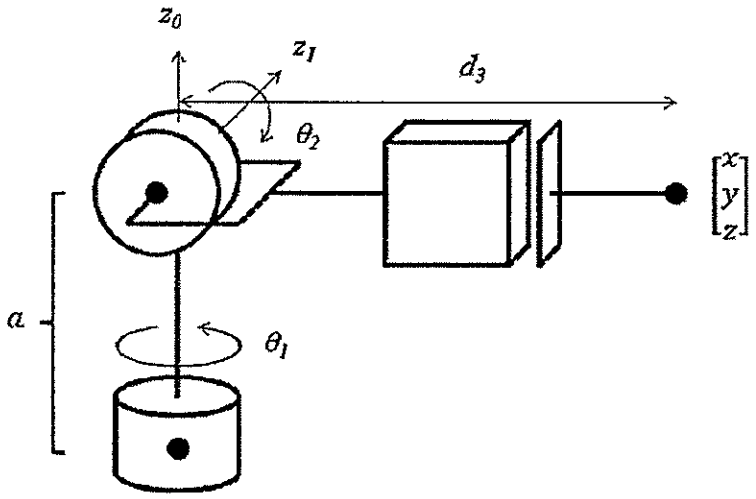

Figure 1. In this figure, θ_1 and θ_2 are shown at 0°

ii. Given the location of the end effector $(x, y, z)^T$, solve the inverse kinematics problem (assume $d_3 \geq 0$).

(40 marks)

2. a) i. Define Jacobian Matrix.

(10 marks)

ii. Consider a two-link robot with shoulder and elbow joints as shown in Figure 2. Find the Jacobian matrix which relates the velocity of the tip to the joint velocities.

(30 marks)

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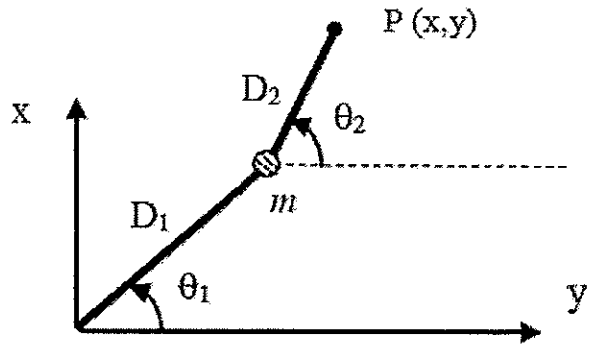

Figure 2.

b)

i. State the Lagrange-Euler (L-E) equation for an n-DOF system, and define all of the variables in it, giving formulas where appropriate.

(20 marks)

ii. Derive the dynamic equation for a two-link revolute joint arm using the L-E method as shown in Figure 3.

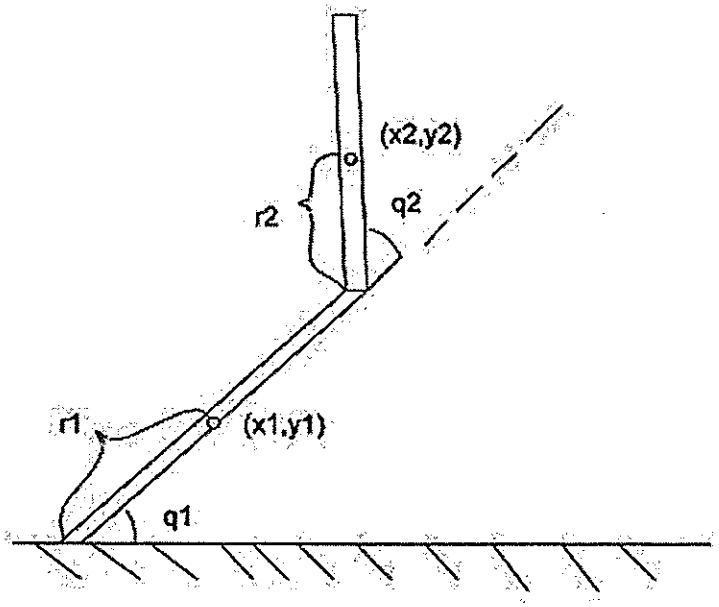

Figure 3.

(40 marks)

3. An end-effector of an articulated robot arm is to move from point A(100, 0, 20) to point B(10, 10, 50) in a straight line in cartesian space in 6 seconds. The end-effector starts to move from a standstill at point A and stops completely at point B.

a) Plan your trajectory in cartesian space to fulfil the above conditions and to avoid sudden jump in acceleration. Please show the step-by-step calculations and write down all the related equations for the trajectory.

(60 marks)

b) Plot your trajectory in the 3D coordinate space and the position, velocity, and acceleration in x-axis, y-axis, and z-axis.

(40 marks)

4. You are tasked to develop a control system for an automatic sliding door using a PLC. The sliding door consists of two motion sensors that detect people approaching from either side of the door. Upon detecting an incoming person, the door will open fully and remain open for 5 seconds before closing again. The door is equipped with limit switches to detect if the door has fully opened or has fully closed. In addition, the door has a manual open button on the inside of the door. Sketch the ladder diagram for the control system. Table 1 below shows the list of the inputs and outputs of the door system:

Table 1. Sliding door inputs and outputs

Inputs/ outputs	**Type**	**Description**
Outside motion sensor	NO	Motion sensor outside of the door
Inside motion sensor	NO	Motion sensor inside of the door
Door open limit switch	NC	Detects if the door has fully opened
Door close limit switch	NC	Detects if the door has fully closed
Door open button	NO	Manual button to open the door
Motor open		Output that control motor open
Motor close		Output that control motor close

(100 marks)

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APPENDIX

Question	Course Outcome (CO)	Programme Outcome (PO)
1	2	PO3
2	3	PO3
3	3	PO3
4	4	PO3