UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2022/2023 Academic Session

July/August 2023

EEM343 – Robotics

Duration : 2 hours

Please check that this examination paper consists of **SIX (6)** 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) (i) Consider the arm shown in Figure 1; solve the forward kinematics problem, i.e. determine the ${}^0T_3$ transformation

(40 marks)

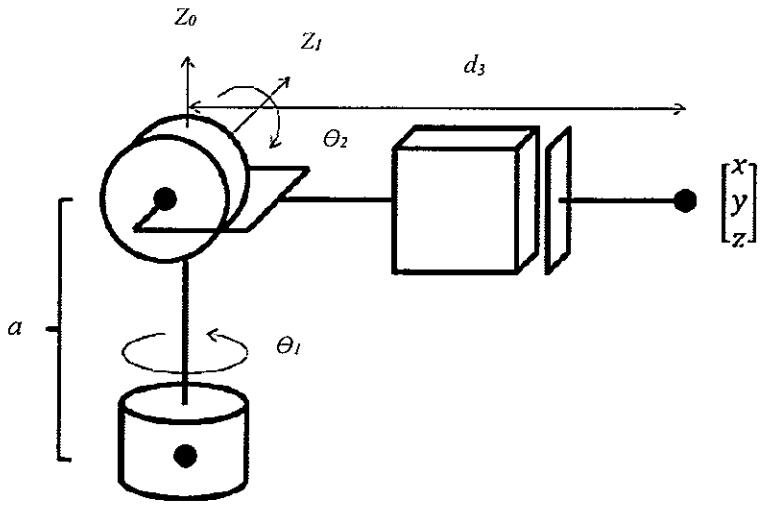

Figure 1. In this figure, θ_1 and θ_2 are shown at 0°

(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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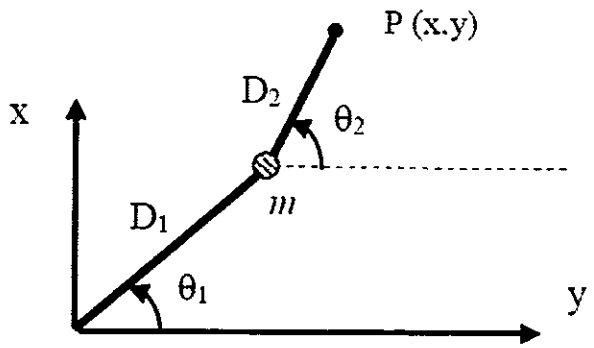

Figure 2.

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.

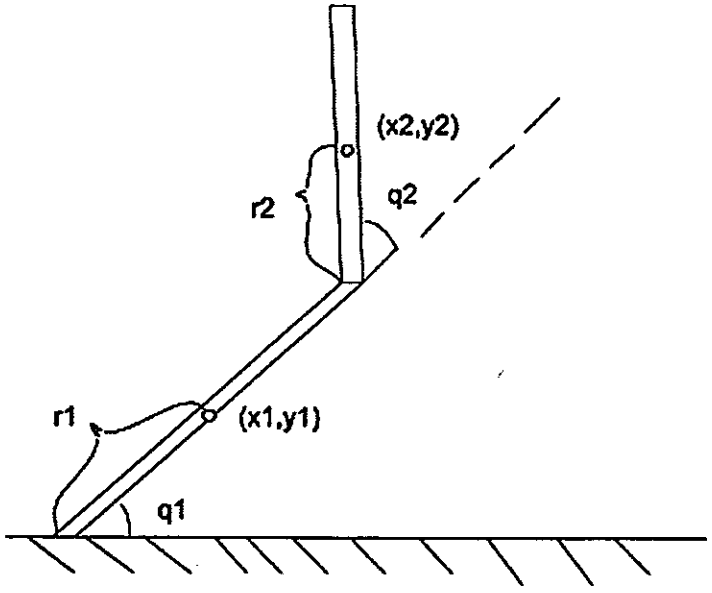

Figure 3.

(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. a) List down and explain the issues related to hydraulic actuators.

(30 marks)

b) Explain how an absolute optical rotary encoder works and what is the difference between this type of encoder and an incremental type of encoder.

(30 marks)

c) An electric motor in one of a robot joints is connected to the joint through a compound gear train shown in Figure 3

(i) If the torque at the output shaft of the motor is 7 g/cm, calculate the torque exerted on the robot joint?

(15 marks)

(ii) If the load inertia at the joint is 0.1 kg.m^2, compute the amount of innertia felt at the motor?

(10 marks)

(iii) What are the drawbacks of using gears in robot joint?

(15 marks)

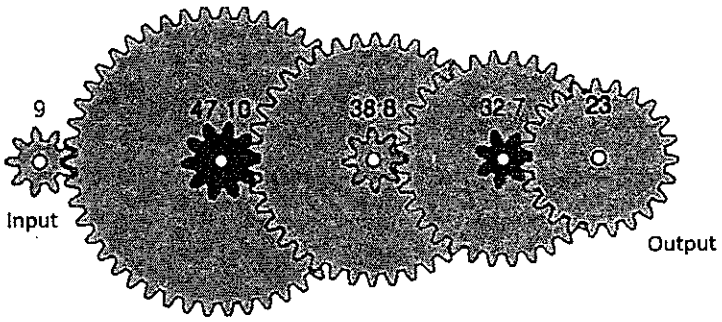

Figure 3. Compound gear train

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APPENDIX

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