GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

Faculty of Engineering

Department of Electrical, Electronic and Telecommunication Engineering

BSc Engineering Degree

Semester 7 Examination – 2025 July

Intake 39 – EE/ET

ROBOTICS

(EE4113)

Time allowed: 3 hours 21 July 2025

ADDITIONAL MATERIAL PROVIDED

The relevant equations are provided at on page no 7.

INSTRUCTIONS TO CANDIDATES

This paper contains 5 questions on 8 pages

Answer ALL questions.

This is a closed book examination

This examination accounts for 70% of the module assessment. The marks assigned for each question and parts thereof are indicated in square brackets

If you have any doubt as to the interpretation of the wordings of a question, make your own decision, but clearly state it on the script

Assume reasonable values for any data not given in or provided with the question paper, clearly make such assumptions made in the script

All examinations are conducted under the rules and regulations of the KDU.

DETAILS OF ASSESSMENT

Learning Outcome (LO)	Questions that assess LO	Marks allocated (Total 70%)
LO1	Q1	15
LO2	Q2,Q3	25
LO3	Q4	10
LO4	Q5	20

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Question 01

a. List and briefly explain three major applications of robots in industry. For each application, mention one advantage compared to manual operation. [5 marks]

b. Explain what is meant by Degrees of Freedom (DOF) in a robot manipulator. How does DOF relate to a robot's workspace and dexterity? 6 - 3 position 3 orientation [4 marks]

c. Classify the industrial robots and briefly describe each type. Geometry, Drive System, Control, Application [3 marks]

d. Differentiate between teleoperated, autonomous, and semi-autonomous robots. Provide one real-world example for each. [3 marks]

Question 02

a. Consider the 3-DoF RPP robot sketched in Fig. Q.2.1 Sketch the geometry of the full robotic manipulator showing frame attachments according to the Denavit-Hartenberg convention and build the associated table of parameters. [5 marks]

b. Based on the parameters given calculate the link transformation ${}^{1}_{3}T$ between the first and third links of the manipulator. [3 marks]

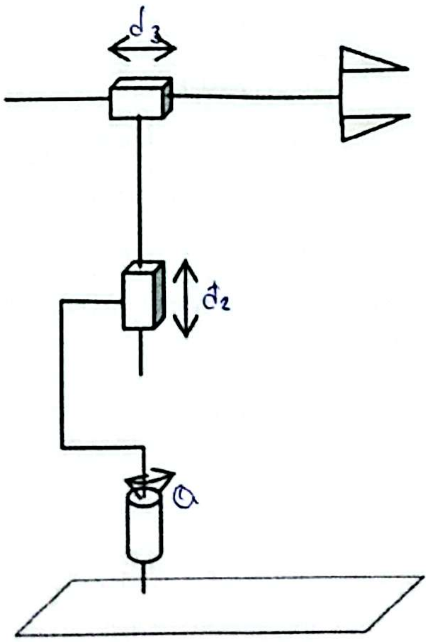

Fig. Q.2.1

c. Figure Q.2.2 represent the 3 link RRP planer manipulator. For the robot's end effector to be at (4.7343, -3.8424, 160°) where the cordinates are given are (x, y, ϕ) relative to the fixed reference frame F. Determine the required joint parameters to achieve this end effector position using inverse kinematics. [7 marks]

Hint: Use 3x3 transformation matrix as this manipulator totally operates on x-y plane only.

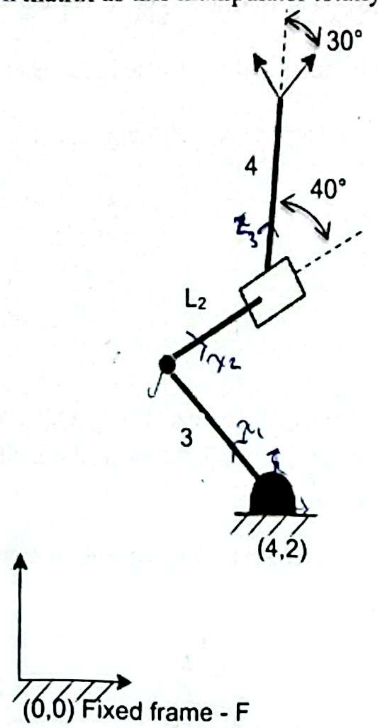

Fig. Q.2.1

Question 03

a. Consider the RRP robot shown in the Fig. Q.3. The home position for the robot has the base of the robot on the ground with $L_1 = 3m$.

The link transformations of the robot are given by,

$$T_1^0 = \begin{bmatrix} c_1 & 0 & -s_1 & 0 \\ s_1 & 0 & c_1 & 0 \\ 0 & -1 & 0 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_2^1 = \begin{bmatrix} c_2 & 0 & -s_2 & 0 \\ s_2 & 0 & c_2 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_3^2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & L_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The inertial velocity of the base frame is zero, ${}_0^0\omega = 0,\ {}_0^0v = 0.$

CamScanner

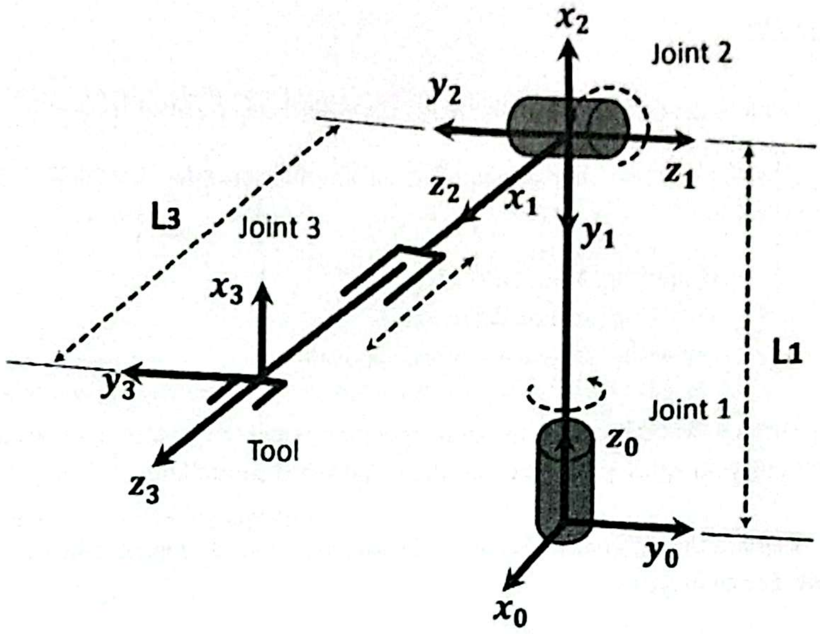

Fig. Q.3

i. Find the Jacobian matrix of the given arm using the velocity propagation method. [6 marks]

ii. Find the linear velocity of the end effector in the configuration shown with joint 1 rotation at 2 $rad/$sec, joint 2 rotating at $-1\ rad/sec$. Assume joint values as $\theta_1 = 0^\circ$, $\theta_1 = -90^\circ$, and $d_3 = 2m$ [2 marks]

iii. Find the joint velocities in the configuration shown if the desired linear velocities of the end effector are: [2 marks]

$0\ m/sec$ on x axis
$4\ m/sec$ on y axis
$2\ m/sec$ on z axis.

Question 04

a. Discuss why via points are important in industrial tasks. [2 marks]

b. A robot joint must move from position $\theta_1 = 10^\circ$ at time $t_1 = 0\ s$ to $\theta_3 = 80^\circ$ at time $t_1 = 4\ s$, passing through a via point $\theta_2 = 50^\circ$ at $t_1 = 2\ s$. [8 marks]

i. Generate a piecewise cubic polynomial trajectory ensuring continuous position and velocity at the via point.

ii. Derive the equations for each segment.

iii. Compute the coefficients of the polynomials.

iv. Sketch the resulting position, velocity and acceleration curves.

Question 05

a. Explain the factors to be considered when selecting a sensor for a robot. [5 marks]

b. Describe the working principle of an absolute encoder. Compare it with an incremental encoder regarding: [6 marks]

i. Output signal format
ii. Power-up position detection
iii. Suitability for safety-critical applications.

c. Discuss the difference between stepper motors and DC motors in robotic applications focusing on operating principles, position controlling, and speed controlling. [3 marks]

d. Explain the differences between electric, hydraulic, and pneumatic actuators used in robotic systems. For each type: [6 marks]

i. Describe the working principle
ii. State typical applications
iii. Highlight advantages and disadvantages

- End of the Question Paper –

Rangl
Accu -
Linea -
Semi -
Repeat
Resolu

Equations

1. General form of Homogeneous Transformation Matrix

$$ {}^{i-1}_{i}T = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1}d_i \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1}d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}. $$

2. Relationship between linear velocities and angular velocities.

$$ \dot{Y} = J(X)\dot{X} $$

3. Velocity propagation equations

a. Revolute joints

$$ {}^{i+1}\omega_{i+1} = {}^{i+1}_{i}R\,{}^{i}\omega_i + \dot{\theta}_{i+1}\,{}^{i+1}\hat{Z}_{i+1} $$

$$ {}^{i+1}v_{i+1} = {}^{i+1}_{i}R({}^{i}v_i + {}^{i}\omega_i \times {}^{i}P_{i+1}) $$

b. Prismatic joints

$$ {}^{i+1}\omega_{i+1} = {}^{i+1}_{i}R\,{}^{i}\omega_i, $$

$$ {}^{i+1}v_{i+1} = {}^{i+1}_{i}R({}^{i}v_i + {}^{i}\omega_i \times {}^{i}P_{i+1}) + \dot{d}_{i+1}\,{}^{i+1}\hat{Z}_{i+1} $$

4. 3D Rotational Matrices

$$ R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} $$

$$ R_y(\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} $$

$$ R_z(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} $$