PPI

TECHNICAL UNIVERSITY OF MOMBASA

School of Engineering & Technology

Department of Electrical & Electronic Engineering

UNIVERSITY EXAMINATION FOR:

BACHELOR OF SCIENCE (ELECTRICAL & ELECTRONIC ENGINEERING)

EEE 4518: ROBOTIC SYSTEMS MODELLING

END OF SEMESTER EXAMINATION

SERIES: AUGUST 2024

TIME: 2 HOURS

DATE: AUGUST 2024

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of FIVE questions. Attempt Question **ONE** and any other **Two** Questions.

Do not write on the question paper.

Question ONE

a) Define the following terms

(i) Manipulator structure

(ii) Open kinematic chain

(iii) Degrees of freedom

[6 marks]

b) Frame {2} is rotated with respect to frame {1} about the x-axis by an angle of 60°. The position of origin of frame {2} as seen from frame {1} is ${}^{1}D_{2} = [7.0\ 5.0\ 7.0]^{T}$.

(i) Obtain the transformation matrix ${}^{1}T_{2}$ which describes frame {2} relative to frame {1}

(ii) Find the description of point P in frame {1} given that ${}^{2}\boldsymbol{P} = [2.0\ 4.0\ 6.0]^{T}$

[8 marks]

c) With the aid of diagrams explain the following types of manipulators

(i) Cartesian manipulator

(ii) Anthropomorphic manipulator

[6 marks]

d) In figure Q1d is 3-DOF manipulator, vector $\boldsymbol{q} = [90^{o}\ -45^{o}\ 100\text{mm}]^{T}$ with $x_1 = 50$ mm and $x_2 = 40$mm. Obtain the position and orientation of tool point $\boldsymbol{P}$.

[10 marks]

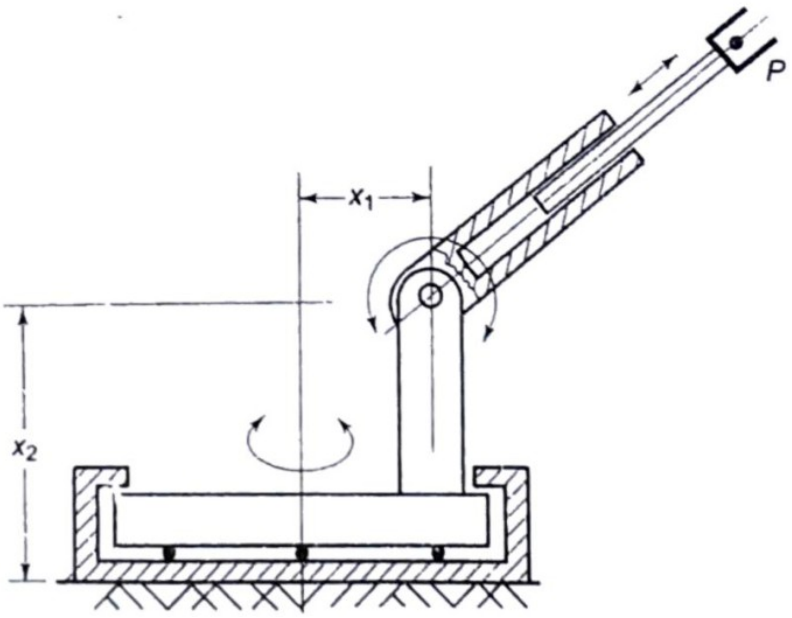

Figure Q1d

Question TWO

a) With the aid of a diagram explain the term **mapping**

[3 marks]

b) Determine Trans(4,−3,7)Rot(y,90◦)Rot(z,90◦)

[4 marks]

c) Figure Q2b. is a two-link manipulator with rotational joints; determine the velocity of the tip of the arm as a function of joint rates. Give the answer in two forms;

(i) in terms of frame {3},

(ii) in terms of frame {0}.

[13 marks]

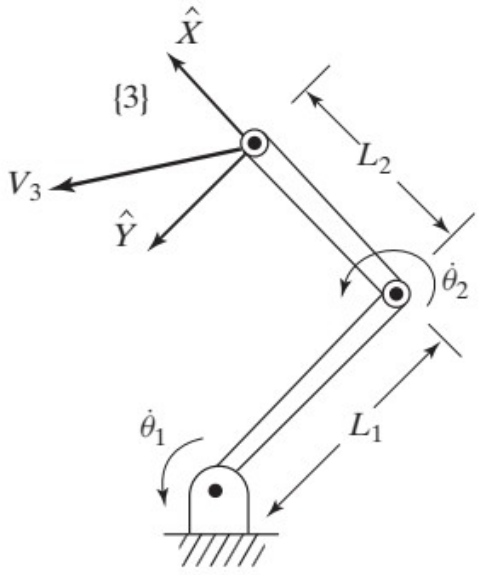

Figure Q2b

Question THREE

a) For the two link mechanism of Figure Q3a is a, derive the dynamic equations using the Lagrangian method hence, determine the equations for the joint torques

[14 marks]

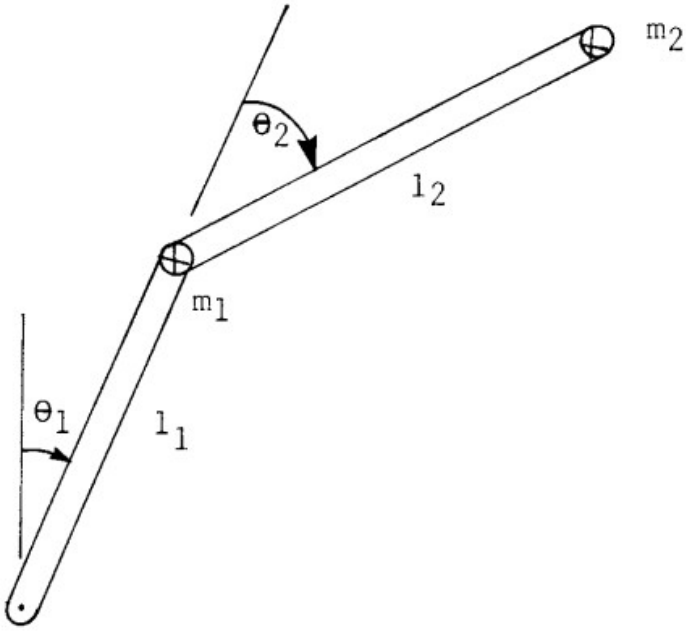

Figure Q3a

b) For figure 3b describe the transformation from frame {R} to frame {Q}

[6 marks]

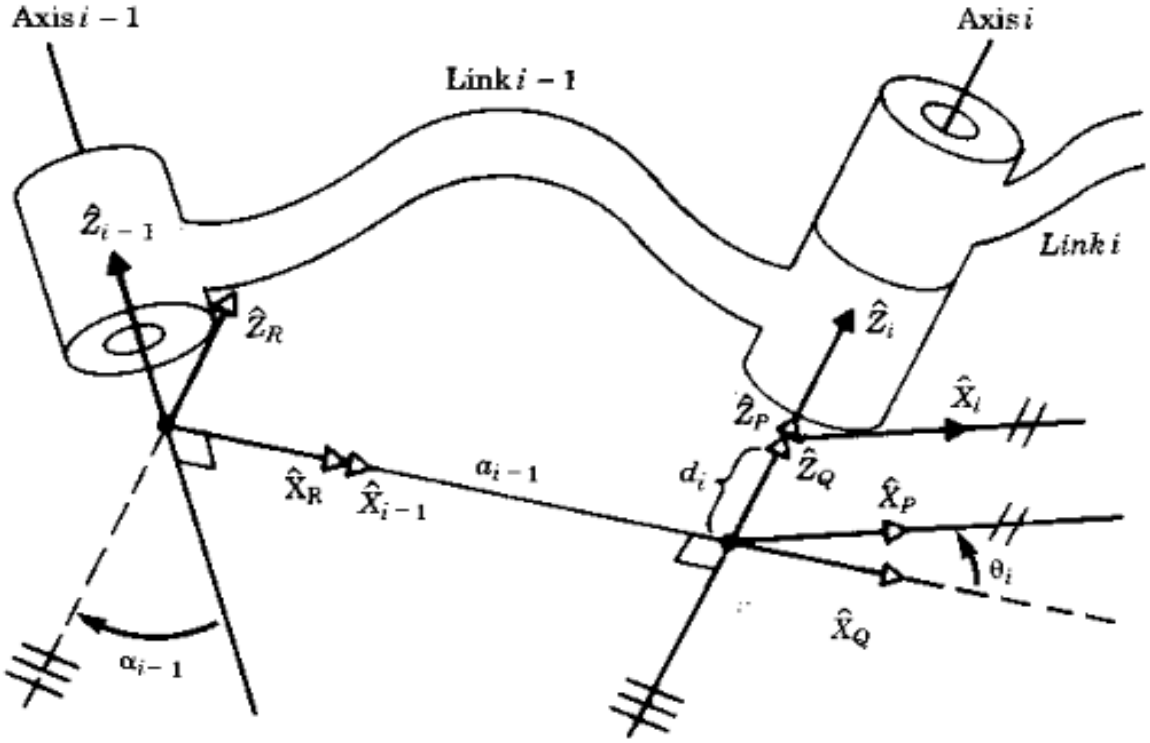

Figure Q3b

Question FOUR

(a) In transformation matrix and coordinate of points, it is possible and sometimes convenient to describe a rigid body motion in terms of known displacement of specified points fixed in the body. Assume *A*, *B*, *C*, and *D* are four points with the following coordinates at two different positions:

$$A_1(2,4,1) \qquad B_1(2,6,1) \qquad C_1(1,5,1) \qquad D_1(3,5,2)$$

$$A_2(5,1,1) \qquad B_2(7,1,1) \qquad C_2(6,2,1) \qquad D_2(6,2,3)$$

Determine the transformation matrix *T* to map the initial positions to the final.

[8 marks]

(b) Determine the equivalent axis and angle of rotation for the matrix given as

$$\mathbf{Rot}(y,90)\mathbf{Rot}(z,90) = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[6 marks]

(c) Determine A_n = Rot(z, θ) Trans(0, 0, d) Trans(a, 0, 0) Rot(x, α)

[6 marks]

Question FIVE

(a) Define the term inverse kinematics

[3 marks]

(b) Apply the geometric approach (inverse kinematics) to determine the joint angles θ_1 and θ_2 for the planar manipulator of Figure Q5b

[17 marks]

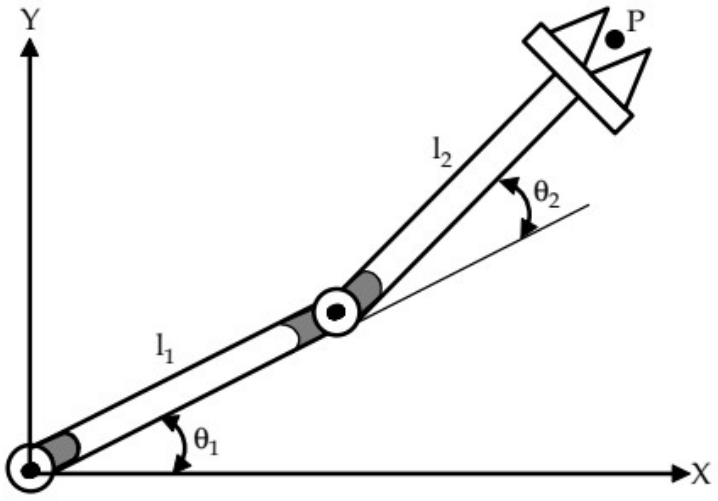

Figure Q5b