PP 2

TECHNICAL UNIVERSITY OF MOMBASA

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

UNIVERSITY EXAMINATION FOR:

BACHELOR OF SCIENCE IN ELECTRICAL & ELECTRONICS ENGINEERING

EEE 4518: ROBOTIC SYSTEMS MODELLING

END OF SEMESTER EXAMINATION

SERIES: NOVEMBER 2025

TIME: 2 HOURS

DATE: November 2025

Instructions to Candidates

You should have the following for this examination
-Answer Booklet, examination pass and student ID
This paper consists of **FIVE** questions.
Answer **QUESTION ONE AND ANY OTHER TWO** questions.
Do not write on the question paper.

QUESTION ONE (30 Marks)

(a) In relation to the study of robotics describe [6 Marks]

(i) The forward kinematics problem for a robotic arm?

(ii) The inverse kinematics problem for a robotic arm

(b) Distinguish between Translation, Rotation and Transformation as used in robotic, give an example in each case. [6 Marks]

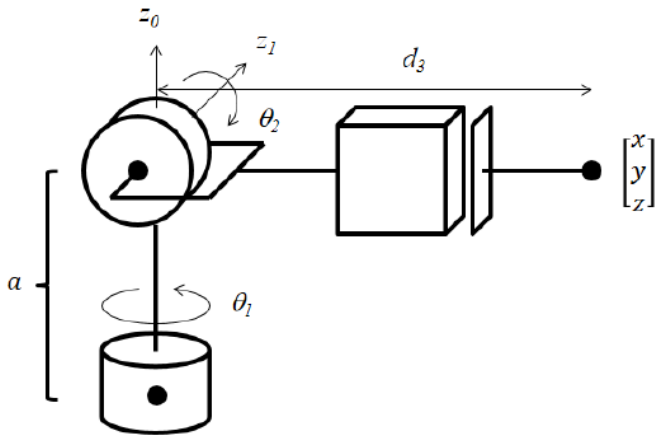
(c) A vector ${}^{A}P$ is rotated about $\hat{Y}_A$ by 30 degrees and is subsequently rotated about $\hat{X}_A$ by 45 degrees. Give the rotation matrix that accomplishes these rotations in the given order. [8 Marks]

(d) Considering the arm shown in Figure 1. [10 Marks]

(i) Solve the forward kinematics problem.

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

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



QUESTION TWO (20 Marks)

(a) Complete or add frames suitable for the Denavit-Hartenberg (DH) convention for the robot shown in Figure 2 and give the table of DH parameters. [10 Marks]

(b) Describe any TWO types of manipulator joints [4 Marks]

(c) A robotics student proposes a course project where they wish to modify an existing differential drive robot to make its left wheel steerable. What is your advice to the student? Justify your answer based on the kinematics of the differential drive. [6 Marks]

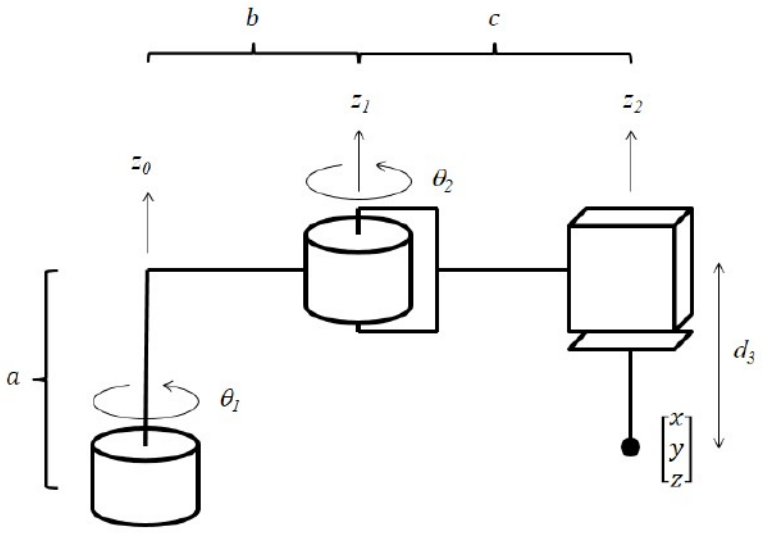


Figure 2. In this figure θ_1 and θ_2 are shown at 0˚

QUESTION THREE (20 Marks)

(a) Describe the following terms as used in robotics [4 Marks]

(i) Velocity motion

(ii) Odometry motion

(b) Sketch ellipses on the axes provided corresponding to the given covariance matrices. The exact dimensions of the ellipses are not important, but the sketches should be reasonable approximations of the true answers. [10 Marks]

(c) Distinguish between joint spaces and Cartesian spaces as used in robotics [6 Marks]

QUESTION FOUR (20 Marks)

(a) Discuss the THREE levels of robot programming [9 Marks]

(b) Suppose that a robot is equipped with a sensor for measuring range and bearing to a landmark, and assume that the sensor can determine which landmark it is currently measuring. Assume that we are performing global localization with an extended Kalman filter. When measuring a single landmark, the probability distribution of the robot location is usually poorly approximated by a Gaussian distribution. When measuring two or more landmarks, the probability distribution of the robot location is usually well approximated

by a Gaussian distribution. Explain why (hint: consider the case where the position and heading of the robot are highly uncertain). [11 Marks]

QUESTION FIVE (20 Marks)

(d) Describe the following terms as employed in robotic [4 Marks]

(i) Trajectory

(ii) Effector

(e) You are designing a robotic arm to perform a pick-and-place operation in a manufacturing setting. The arm needs to pick objects from one location and place them at another. Describe the key aspects of trajectory planning for this robotic arm, including the methods and considerations involved. Provide a step-by-step explanation of how you would plan the trajectory for this task. [10 Marks]

(f) Distinguish between joint spaces and Cartesian spaces as used in robotics [6 Marks]