



MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM 509: ROBOTICS AND AUTOMATION

DATE: 16/5/2019

TIME: 8.30-10.30 AM

INSTRUCTIONS:

Answer Question One and Any Other Two Questions

All working must be clearly shown

QUESTION ONE (20 MARKS)

- a) Define the following terms as used with industrial robotics. (5 marks)
- i. Payload
 - ii. Orientation axes
 - iii. Repeatability
 - iv. Control resolution
 - v. Work envelope
- b) Define degeneracy and give two conditions under which a robot may become degenerate. (3 marks)
- c) Explain five basic components of a robot. (5 marks)
- d) A point $P = (7 \ 3 \ 2)^T$ is attached to uvw frame and is subjected to rotation of 90° about z-axis followed by rotation of 90° about y-axis and finally a translation of $(4, -3, 7)$. Find the coordinates of the point relative to the reference frame at the conclusion of transformation. (7 marks)

QUESTION TWO (20 MARKS)

A special three-degree-of freedom spraying robot has been designed as shown in Fig. Q2.

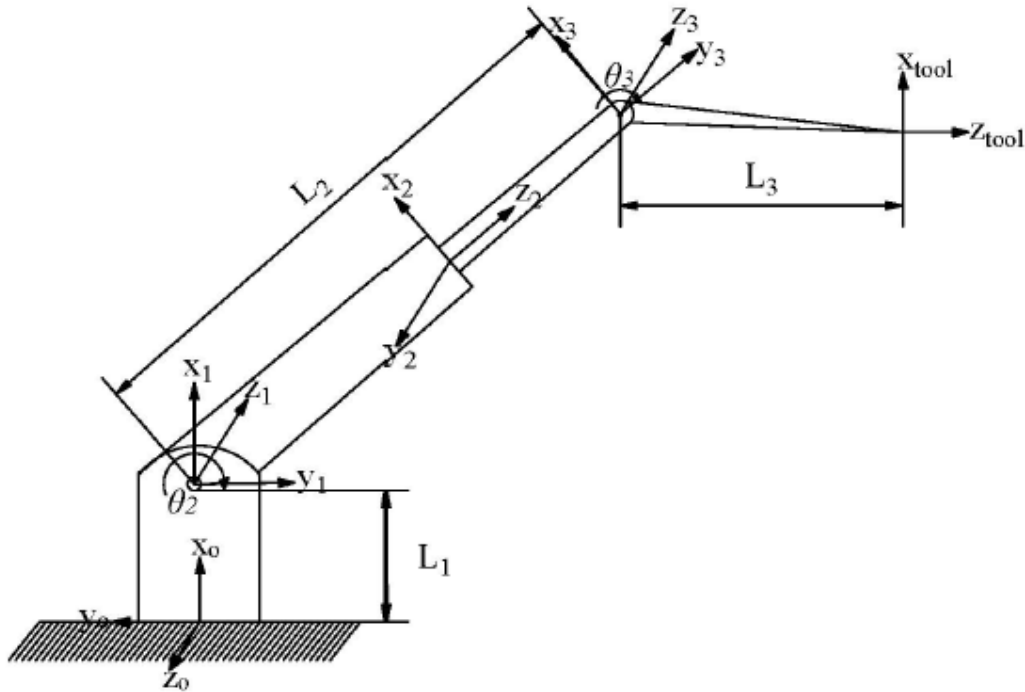


Fig. Q2

- Assign the coordinate frame based on the D – H representation.
- Fill out the link parameter table
- Write the ${}_{k-1}^kH$ for $k = 1, 2, 3$.
- For fixed l_2 (2 degree of freedom robot) and ${}^{tool}_0H = \begin{bmatrix} 1 & 0 & 0 & x \\ 0 & 0 & -1 & y \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$, find θ_i for $i=1,2$.

Assume that point $(x, y, 0)$ is within the workspace of the robot (20 marks)

QUESTION THREE (20 MARKS)

- Differentiate forward kinematic problem from inverse kinematic problem. Why the inverse kinematic problem is more difficult to solve. (5 marks)
- Coordinate system B is initially aligned with coordinate system A. It is translated to the point $(5, 4, 1)^T$ and then rotated 30 degrees about its x-axis. Lastly, the coordinate system is rotated 60 degrees about an axis that passes through the point $(2, 0, 2)^T$, measured in the

current coordinate system, which is parallel to the y-axis. Find ${}^B_A T$. (9 marks)

- c) It is desired to place the origin of the hand frame of a cylindrical robot (Fig. Q.3(c)) at $(3 \ 4 \ 7)^T$. Calculate the joint variables of the robot. (6 marks)

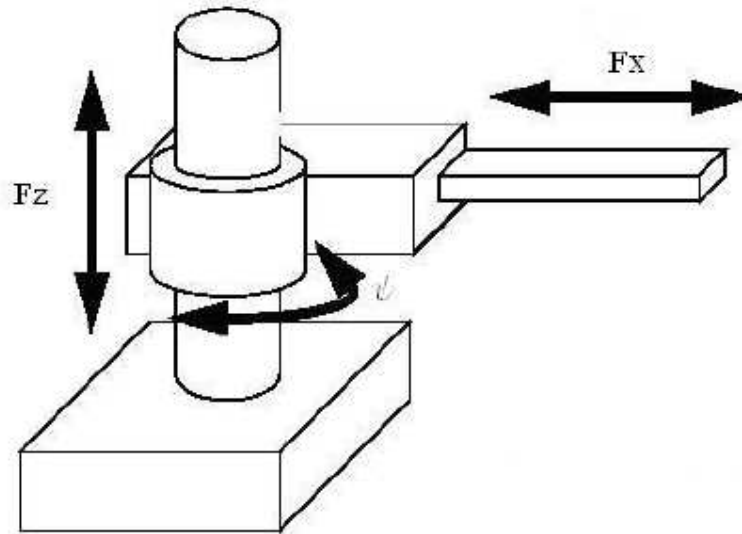


Fig. Q3(c)

QUESTION FOUR (20 MARKS)

- Describe the three types of joints commonly found in robots. (3 marks)
- With an aid of diagrams classify robots based on their basic configuration and explain each class.
 - List four typical applications where a mobile robots would find use as opposed to arm-fixed robots. (10 marks)
- Mechanical grippers are the most common types of grippers used in robotic applications. What are some of innovations and advantages that make them common? (4 marks)
- Explain three types of joint drive that are used in robotics. (3 marks)

QUESTION FIVE (20 MARKS)

- Explain why forward/inverse kinematics is necessary in trajectory planning
 - Explain any four challenges met during direct/inverse modelling that affect trajectory planning. (6 marks)
- What do you understand by controllability as used in modern control design? (2 marks)
- What is the difference between powered lead-through and manual lead-through in robot programming? (2 marks)
- Discuss four main classifications of robot control systems. (10 marks)

Standard transformations

- D-H representation

$${}^k_{k-1}H = \begin{bmatrix} \cos \theta_k & -\cos \alpha_k \sin \theta_k & \sin \alpha_k \sin \theta_k & a_k \cos \theta_k \\ \sin \theta_k & \cos \alpha_k \cos \theta_k & -\sin \alpha_k \cos \theta_k & a_k \sin \theta_k \\ 0 & \sin \alpha_k & \cos \alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

- Rotation about x-axis

$$\mathbf{R}_{x,\alpha} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \alpha & -\sin \alpha \\ 0 & \sin \alpha & \cos \alpha \end{bmatrix} \quad (2)$$

- Rotation about y-axis

$$\mathbf{R}_{y,\beta} = \begin{bmatrix} \cos \beta & 0 & \sin \beta \\ 0 & 1 & 0 \\ -\sin \beta & 0 & \cos \beta \end{bmatrix} \quad (3)$$

- Rotation about z-axis

$$\mathbf{R}_{z,\gamma} = \begin{bmatrix} \cos \gamma & -\sin \gamma & 0 \\ \sin \gamma & \cos \gamma & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (4)$$