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 be come 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^o about z-axis followed by rotation of 90^o 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.

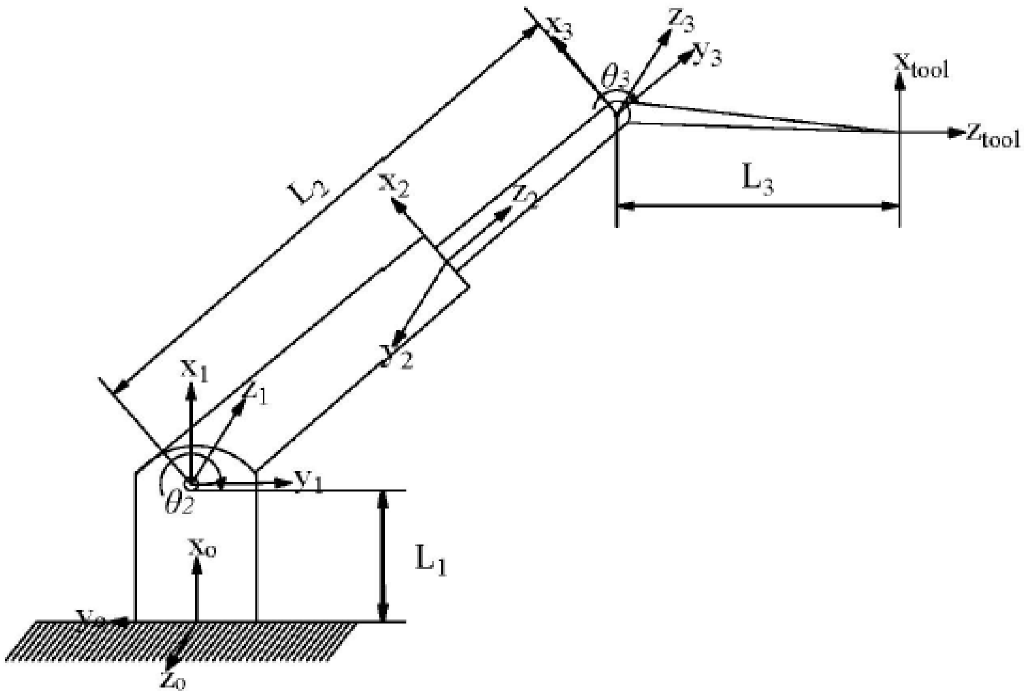

Fig. Q2

a) Assign the coordinate frame based on the D – H representation.

b) Fill out the link parameter table

c) Write the ${}_{k-1}^{k}H$ for k = 1, 2, 3.

d) For fixed l_2 (2 degree of freedom robot) and ${}_{0}^{tool}H = \begin{bmatrix} 1 & 0 & 0 & x \\ 0 & 0 & -1 & y \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$, 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)

a) Differentiate forward kinematic problem from inverse kinematic problem. Why the inverse kinematic problem is more difficult to solve. (5 marks)

b) 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)

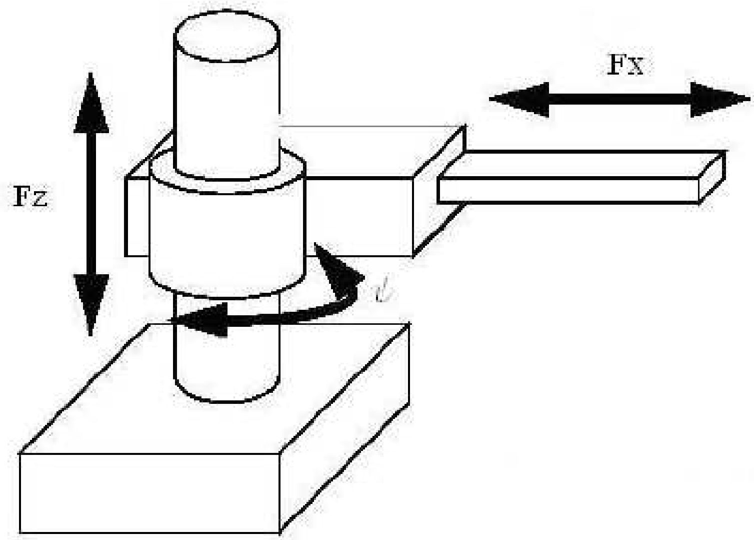

Fig. Q3(c)

QUESTION FOUR (20 MARKS)

a) Describe the three types of joints commonly found in robots. (3 marks)

b) (i) With an aid of diagrams classify robots based on their basic configuration and explain each class.

ii) List four typical applications where a mobile robots would find use as opposed to arm-fixed robots. (10 marks)

c) 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)

d) Explain three types of joint drive that are used in robotics. (3 marks)

QUESTION FIVE (20 MARKS)

a) i) Explain why forward/inverse kinematics is necessary in trajectory planning

ii) Explain any four challenges met during direct/inverse modelling that affect trajectory planning. (6 marks)

b) What do you understand by controllability as used in modern control design? (2 marks)

c) What is the difference between powered lead-through and manual lead-through in robot programming? (2 marks)

d) Discuss four main classifications of robot control systems. (10 marks)

Standard transformations

- D-H representation

$$
{}_{k-1}^{k}H = \begin{bmatrix} \cos\theta_k & -\cos\alpha_k \sin\theta_k & \sin\alpha_k \sin\theta_k & a_k \cos\theta_k \\ \sin\theta_k & \cos\alpha_k \cos\theta_k & -\sin\alpha_k \cos\theta_k & a_k \sin\theta_k \\ 0 & \sin\alpha_k & \cos\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}
$$

- Rotation about x-axis

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

- Rotation about y-axis

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

- Rotation about z-axis

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