ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

SEMESTER II EXAMINATION, 2017/2018 ACADEMIC SESSION

COURSE TITLE: ROBOTICS AND AUTOMATION

COURSE CODE: ECE526

EXAMINATION DATE: AUGUST, 2018

COURSE LECTURER: DR O. K. OGIDAN & MR. ONILE, ABIODUN E.

TIME ALLOWED: 2 HOURS

HOD's SIGNATURE

INSTRUCTIONS:

1. ANSWER ANY **FOUR QUESTIONS**
2. ANY INCIDENT OF MISCONDUCT, CHEATING, POSSESSION OF UNAUTHORIZED MATERIALS DURING EXAM SHALL BE SEVERELY PUNISHED.
3. YOU ARE **NOT** ALLOWED TO BORROW CALCULATORS AND ANY OTHER WRITING MATERIALS DURING THE EXAMINATION.
4. ELECTRONIC DEVICES CAPABLE OF STORING AND RETRIEVING INFORMATION ARE PROHIBITED.
5. DO **NOT** TURN OVER YOUR EXAMINATION QUESTION PAPER UNTIL YOU ARE TOLD TO DO SO.

QUESTION 1

a) Derive the inverse kinematics for a two-link planar robot, given (x, y) coordinate. **(2 marks)**

b) Using Denavit-Hartenberg convention, write out the forward kinematics homogenous transformation representation of the robotic system illustrated in Figure 1 **(5 marks)**

Hint: Remember to label the links, joints and origin appropriately

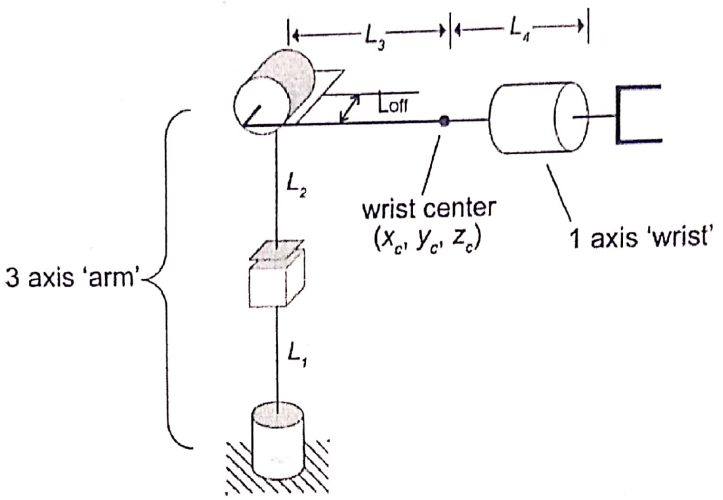

Figure 1.0: A 4 DOF Robot

c) Robotic manipulators have evolved over years with a range of application in material handling.

i. Briefly explain what you understand by manipulator dynamics. **(1 mark)**

ii. Determine the possible configuration of the robot shown in Figure 1.0 and draw its associated work space. **(2 marks)**

d) i. Derive the expression for Euler-Lagrange equation from the Lagrangian described in the equation 1.0. **(3 marks)**

$$\mathcal{L} = \mathcal{K} - \mathcal{P} \qquad (1.0)$$

ii. Rotational joints are represented by R and Prismatic joints are represented by P, how many joints are located on a standard robotic WRIST? **(2 mark)**

QUESTION 2

a) A robotic manipulator optimised for spraying paint is fabricated as four link anthropomorphic geometry and fixed to a base that moves on a rail. The Denavit – Hertenberg parameters of the PRRRR classed robot are given Table 1.0.

Table 1.0: D-H Parameters

Link	**α**	***ai***	***θi***	***di***
0	0	0	0	k1
1	-90	0	θ2	1
2	+90	0	θ3	0.5
3	0	0.5	θ4	0
4	-90	0	θ5	0.9

i. Sketch the geometry representing the world frame (0) and the first link frame (1) in the proper geometry. Clearly show the frame orientations **(3 mark)**

ii. Sketch as a separate diagram the geometry representing the frame (2) and the third link frame (3) in the proper geometry. Clearly show the frame orientations **(3 mark)**

b) Explain the various stages/features in robotic programming. Briefly explain any two types of robot control that you know **(5 mark)**

c) Robot software is a set of coded instruction that instructs the electrical and mechanical components of a robot, what action to perform.

i. Itemise any four methods for programming a robot **(1 marks)**

ii. Briefly describe any three examples of robot programming languages **(3 marks)**

ION 3

Kinematics studies the inter-relationship existing between objects that are in motion.

a) i. Define the term forward kinematics of a robot **(2 marks)**

ii. Define the term reverse kinematics of a robot **(2 marks)**

b) Given in Figure 2 is a three (3) joint robot manipulator.

i. Proffer solution to the forward kinematic problem **(4 marks)**

ii. Develop the table representing the Denavit-Hatnberg parameters for the manipulator in Figure 2. **(3 marks)**

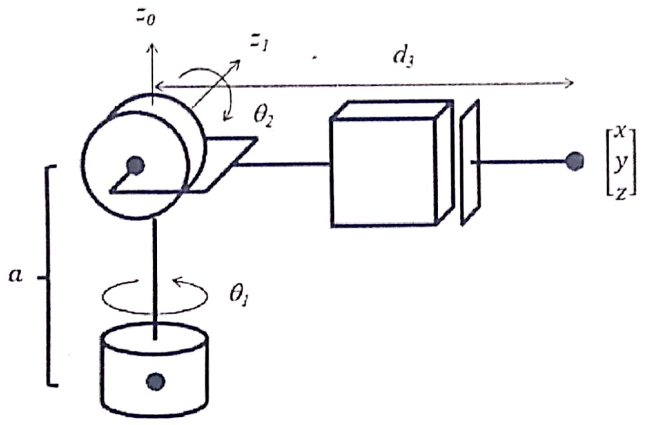

Figure. 2: A 3 Joint Robot Geometry

c) Solve the inverse kinematics problem presented in Figure 2, given that link d3 >= 0 and the end effector location is (x, y, z) T **(4 marks)**

Hint: Rotation matrix about x, y and z axes, and Homogeneous transformation matrix are given by:

$$R_X = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & -sin\theta \\ 0 & sin\theta & cos\theta \end{bmatrix} \quad R_Y = \begin{bmatrix} cos\theta & 0 & sin\theta \\ 0 & 1 & 0 \\ -sin\theta & 0 & cos\theta \end{bmatrix} \quad R_Z = \begin{bmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$H = \begin{bmatrix} C\theta & -S\theta C\alpha & S\theta S\alpha & rC\theta \\ S\theta & C\theta C\alpha & -C\theta S\alpha & rS\theta \\ 0 & S\alpha & C\alpha & d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

QUESTION 4

a) You have been asked to develop a visual servo-based robot using RGB camera. Your robot processes the ability to detect and classify objects; describe the stages involved in processing the image obtained from the camera with a detailed sketch. **(4 marks)**

(i) What are the two types of robot joints that are available? Define the Degree of Freedom (DOF) of a robot **(2 marks)**

b) Explain with the aid of a neat diagram, the three-wrist motion associated with a robot wrist **(2 marks)**

c) Itemize the sources of energy in robots. Describe the important features of servo and stepper motors by emphasizing their limitations **(5 marks)**

QUESTION 5

a.) What do you understand by automated control system? **(2 marks)**

b.) With the aid of well labelled diagram (where necessary) discuss the differences between fixed/permanent automation and flexible/programmable automation. **(4 marks)**

c.) Briefly discuss the following (include diagrams where necessary)

i.) Pneumatic control system **(1 marks)**

ii.) Hydraulic control system **(1 marks)**

iii.) Electrical control system **(1 marks)**

d.) Consider the system given in Figure 3 where an electric motor is driving a gear train which is driving a winch. The motor (under these conditions) turns at 100 rpm for each Volt (V) supplied; the output shaft of the gear train rotates at one-half of the motor speed; the winch (with a 3-inch shaft circumference) converts the rotary motion (rpm) to linear speed.

i.) Calculate the overall transfer function of the system **(4 marks)**

(2 marks)

ii.) Calculate the system output

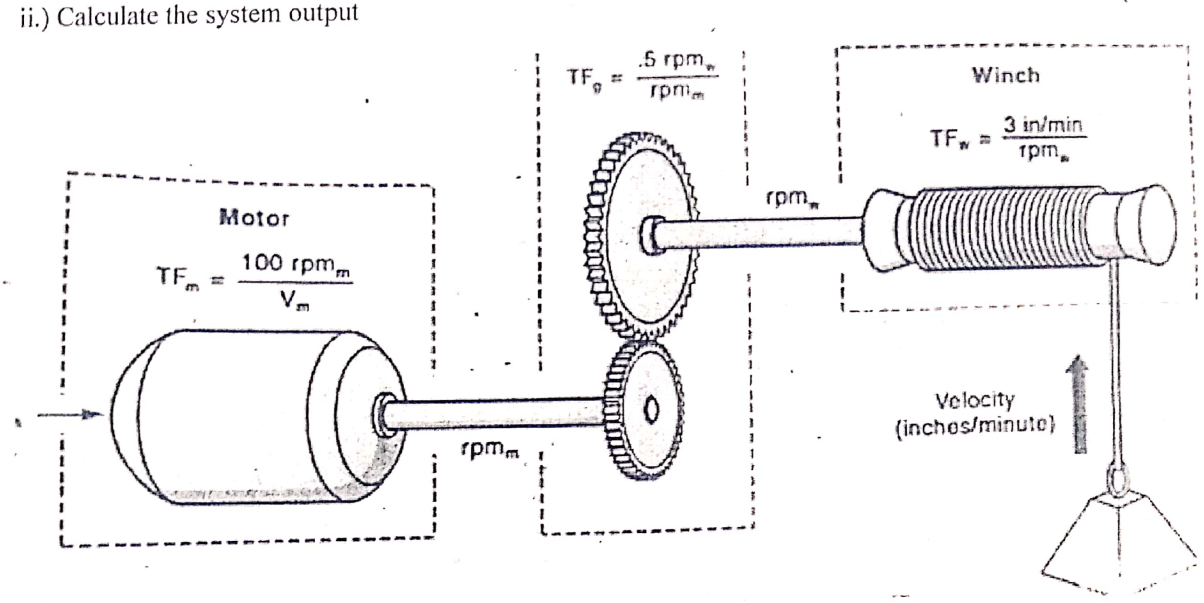

Figure 3: System with three transfer function

QUESTION 6

a.)

i.) Briefly describe the operations of: open loop control system and Closed loop control system **(3 marks)**

ii.) What are the differences between open loop and closed loop control? **(2 marks)**

b.) List the programming languages commonly used for programmimg a Programmable Logic Controllers (PLC) **(2 marks)**

c.) Write a program in ladder language to control the level of water in a storage tank shown in Figure 5 by turning a discharge pump on/off. The modes of operation are as follows: **(8 marks)**

Off position – The water will stop if it is running and will not start if it is stopped

Manual Mode – The pump will start if the water in the tank is at any level except low.

Automatic Mode – If the level of water in the tank reaches a high point, the water water pump will start so that water can be removed from the tank, thus lowering the level.

When water level reaches a low point, the pump will stop

Status light Indicator

Green – water pump is running

Yellow – High water level status

Red – Low water level status

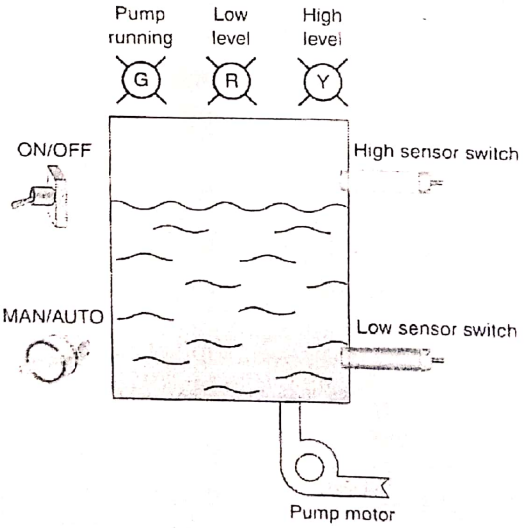

Figure. 5: Water flow control

(8 marks)