First Semester Examination
2023/2024 Academic Session

Februari 2024

EPC 451 – Robotic and Smart Factory
(Robotik dan Kilang Pintar)

Duration: 3 hours
(Masa: 3 jam)

Please check that this examination paper consists of <u>EIGHT</u> (8) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LAPAN (8) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions :   Answer **ALL FIVE (5)** questions.

*[**Arahan** : Jawab **LIMA (5)** soalan]*

1.   [a]   Smart factory are usually associated with automation and integration of sensors. However, automation already existed since the introduction of the first Programmable Logic Controllers (PLCs), which marked the start of Third Industrial Revolution. Using your words, discuss what is meant by "Smart" in smart factory and how smart factory are considered as 'digital factory'.

(30 marks)

[b]   In your hometown, there are clusters of small and medium enterprises involved with salted duck eggs production. After close inspections, you found that this industry cannot be expanded further because there are too many spoiled egg due to improper incubation and the operation still relying on traditional method as shown in Figure 1[b]. As a future engineer, you were tasked by village chief to build a centralized smart duck eggs incubator. Below is the parameter for duck egg hatching system:

- Hatching time : 28 days
- Incubator temperature : 37°C - 39 °C
- Humidity : 50% - 60%

(i)   With your prior knowledge, build a basic 3-layer IoT system architecture for the project with all the sensors and equipment required and communication method from each layer to other layers.

(40 marks)

(ii)   After a few weeks of your factory operation, you find out that there are hackers attacking your IoT system. The hackers are most probably from nearby village (<1km). Modify your system in [b](i) that would help from the hacking occur again in the future.

Figure 1[b]

(30 marks)

...3/-

2.   [a]   Figure 2[a] shows a type of robot that found servicing customer at Big Tas'
Tea Restaurant, Taman Pekaka Indah, Nibong Tebal.

(i)   Identify and describe this type of robot

(20 marks)

(ii)   Describe the selection criteria of robot application in this service
industry.

Figure 2[a]

(20 marks)

[b]   Figure 2[b] shows a robot manipulator used under the racing game
simulator. By analyzing the robot geometry, elaborate on the mechanical
structure of this manipulator.

Figure 2[b]

(30 marks)

[c]   A robot is essentially a movable open chain of successively coupled bodies with one end fixed to the ground and the free end containing an end effector. The bodies of the open chain are usually linked which are joined together by some lower pair connectors. State and describe FIVE (5) of the most common types of lower pair connectors.

(30 marks)

3.   [a]   Describe THREE (3) types of inline forms used in Kuka Robot motion. Choose ONE (1) of them and provide a sketch illustrating its inline form.

(20 marks)

[b]   The Advanced Composite Group plans to optimize the trimming and drilling processes by employing a Kuka Robot equipped with an INNOTO4COM bit. This versatile bit is capable of drilling holes of 4.85 mm and 6.35 mm diameters, as well as performing the trimming process, all in a single application. Refer to Figure 3[b] for a detailed illustration of the bit. The trimming procedure involves working around the panel and performing a rebore process, as depicted in Figure 3[b]. Subsequently, the process entails drilling one hole with a diameter of 4.85 mm and three holes with diameters of 6.35 mm. Sketch the motion of Kuka Robot to complete the whole process and also include the related points in your sketch.
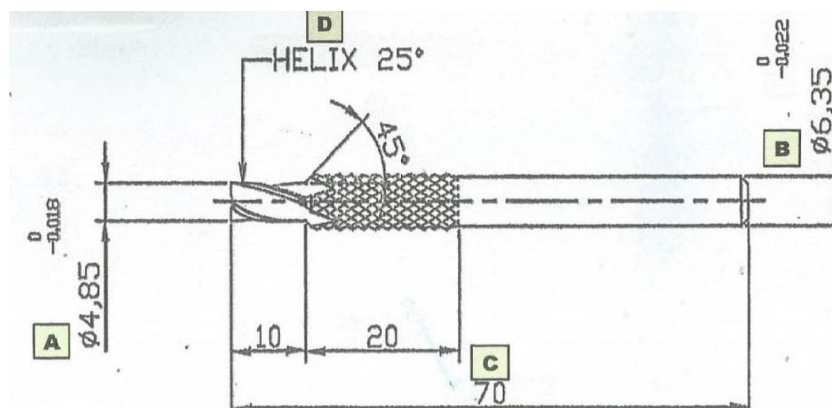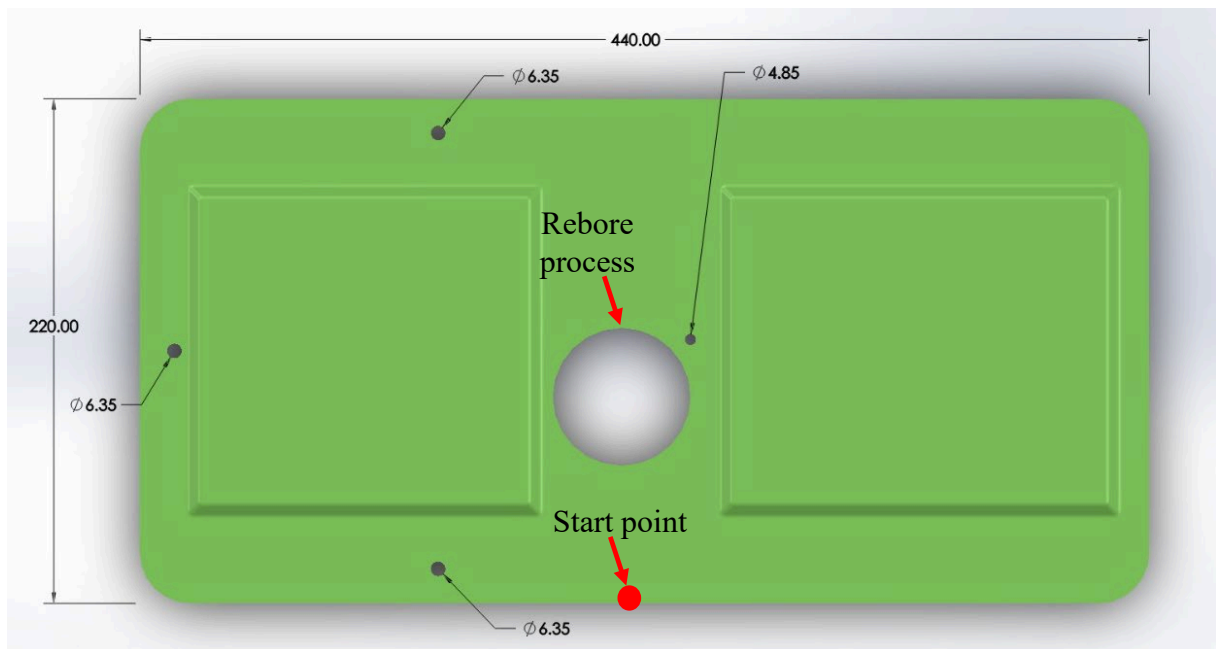
Figure 3[b]

(30 marks)

[c]   Develop a program for Kuka Robot for the trimming and drilling processes, and determine a suitable robot speed if the process needs to be improved to 50% from the current time. You may use an assumption in your justification.

(50 marks)

4.   [a]   Give a definition of robot arm kinematics. Explain the use of forward and inverse kinematics in robotics.

(10 marks)

[b]   Refer to a type robot in Figure 4[b].

   (i)   Assign the coordinate frames based on the Denavit-Hartenberg representation.
   (ii)   Construct the parameter table.
   (iii)   Write all the transformation matrices.
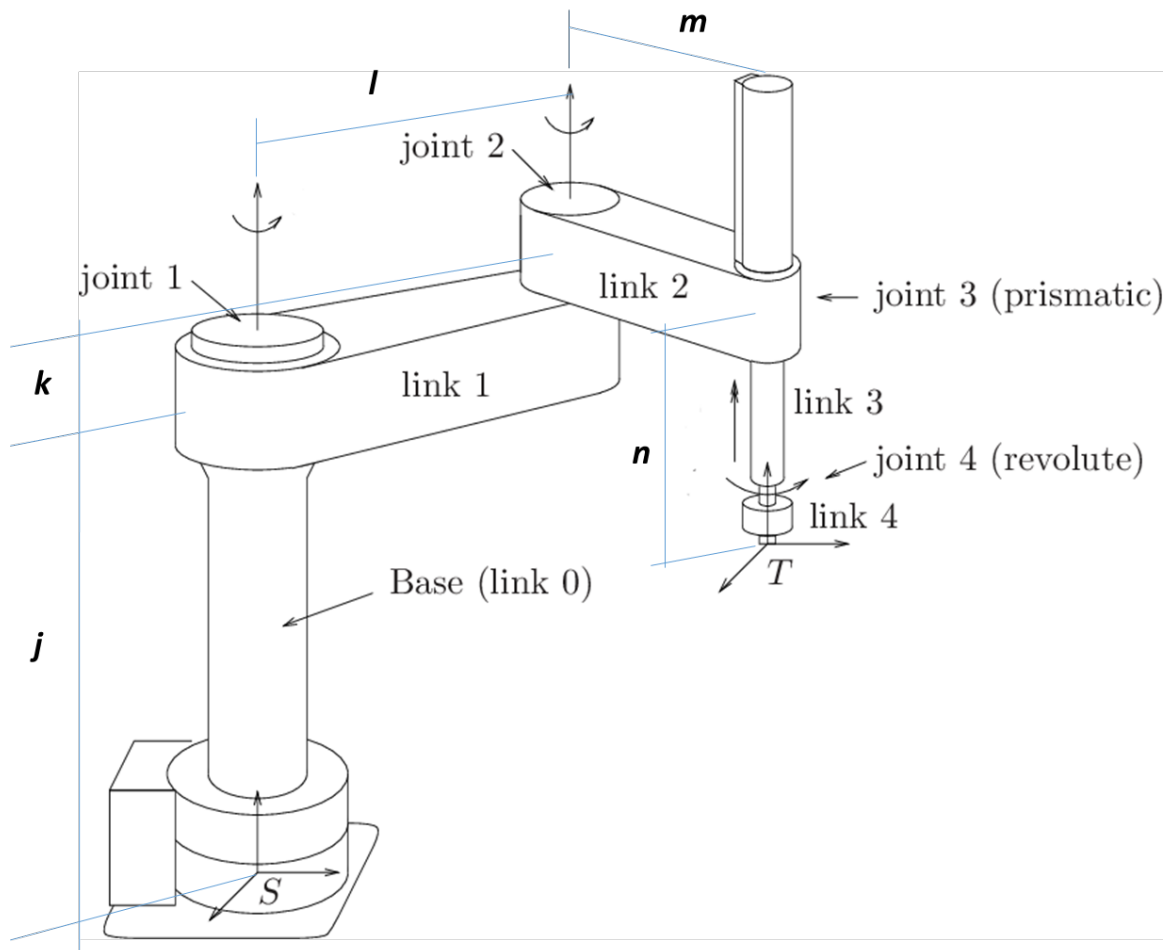   (iv)   Write the T_S^T matrix using the transformation matrices in (iii).

Figure 4[b]

(60 marks)

[c]   The desired final position and orientation of the gripper of a Cartesian RPY robot is given below. Find the necessary RPY angles and displacements. Sketch the position of P in origin axes.

$$
{}^{R}T_{P} = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.346 & -0.719 & 0.603 & 0.696 \\ 0.742 & 0.603 & 0.292 & 0.595 \\ -0.574 & 0.346 & 0.742 & 0.123 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

(30 marks)

5.   [a]   Industry 4.0 solutions lead to value innovation, increased revenues, market share, and profits, mainly through much more reliable and consistent productivity and output. The empowerment to manufacture complexes configure-to-order products on a mass scale, in a cost-efficient way, is just one of the benefits Industry 4.0 is set out to address. Discuss in detail the benefit of industry 4.0 to the company in terms of costs, complexity, and productivity.

(30 marks)

[b]   Figure 5[b] shows an accomplished automated system for sorting two product types from the production line using a robot arm. Based on your knowledge, identify FIVE (5) components that are necessary to use for assembly for this automation.
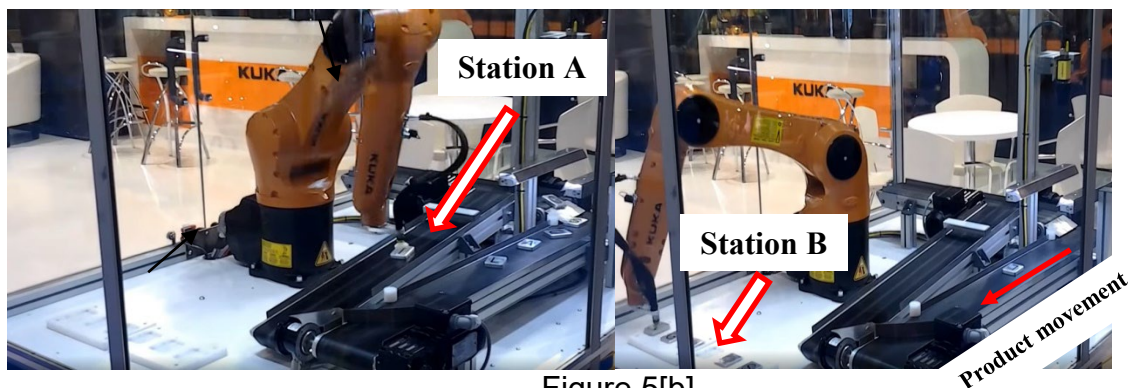

Figure 5[b]

(20 marks)

[c]   Develop a Kuka Robot program designed to facilitate the separation of the product from the conveyor to both Station A and Station B, as illustrated in Figure 5[b]. The program should encompass execution control, subprograms, and functions to ensure the seamless operation of the entire process.

(50 marks)

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