First Semester Examination
2022/2023 Academic Session

February 2023

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>SIX</u> (6) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi <u>ENAM</u> (6) muka surat yang bercetak sebelum anda memulakan peperiksaan ini].

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

*[<u>Arahan</u> : Jawab **KESEMUA LIMA (5)** soalan.]*

1.   [a]   In 1950, Isaac Asimov came up with the law of robotics. Please state the law.

(30 marks)

      [b]   (i)   A company that are producing Batik ask you to design a robot that can draws Batik's motives on cloths using hot wax as ink. Figure 1[a] is the preliminary design for the robot and Figure 1[b] show the driving system for the robot. Explain the robot effector, the robot manipulator configuration, its degree of freedom, the working envelope, the links and joints for the robot and the sensors required for this robot.
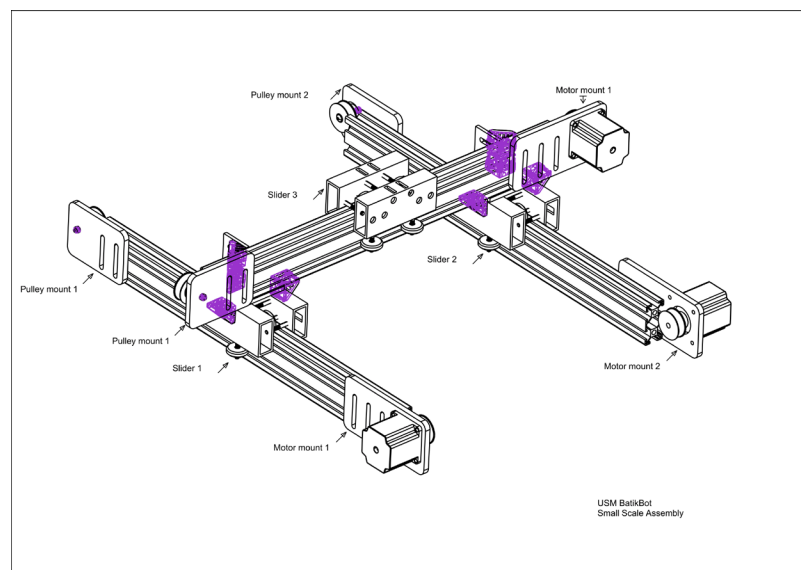

Figure 1[a]

(30 marks)

Figure 1[b]

(ii)   Based on your answer in 1b(i), using your own word, explain the operation of the robot and its limitation. You may use diagram to help visualization.

(40 marks)

2.   [a]   Discuss the degree of mobility, steerability and maneuverability for a differential drive type wheeled mobile robot.

(25 marks)

[b]   Figure 2[b] shows a LEGO Mindstorms EV3 program for a wheeled mobile robot with its wheels are driven by two large motors connected to Port B and C and has an ultrasonic sensor connected to Port 4. Explain the movement of the robot toward an object when the program is downloaded and executed.

Figure 2[b]

(25 marks)

[c]   Figure 2[c] shows a LEGO Mindstorms EV3 program for a wheeled mobile robot with its wheels are driven by two large motors connected to Port B and C and has a gyro sensor connected to Port 2. Explain the movement of the robot when the program is downloaded and executed.
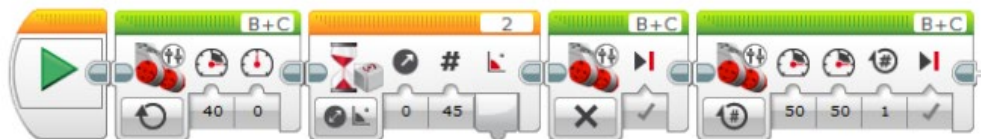

Figure 2[c]

(25 marks)

[d]   A differential wheeled mobile robot, which has 60 mm wheel diameter, is travelling in a curve with left and right wheel speed 800 rpm and 600 rpm respectively. Calculate the length of the curve path travelled for 30 seconds if the robot needs to accelerate and decelerate in 3 seconds. Given the length of path is $D = \frac{r}{2}\left(\frac{\omega_L + \omega_R}{2}\right)(t_3 - t_0 + t_2 - t_1)$ where r is the wheel radius, ω_L is left wheel speed, ω_R is right wheel speed, t_0 is initial time travelled, t_1 is time after accelerating, t_2 is time before decelerating and t_3 final time travelled.

(25 marks)

…4/-

3.   [a]   Figure 3[a] shows the component that needs to be attached with other components using sealant application. Determine the motion type that can be programmed for Region A and justify your answers.
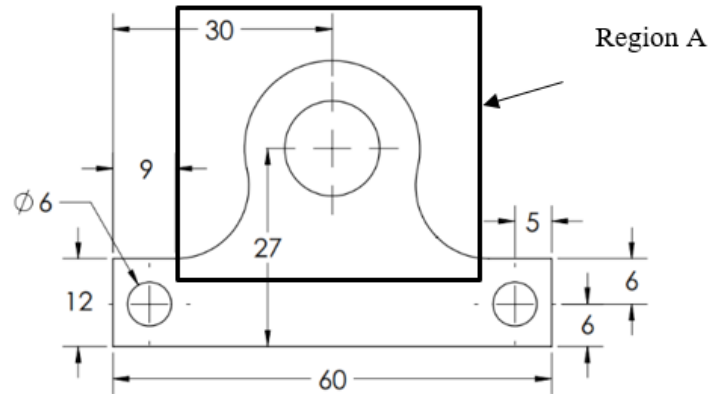

Figure 3[a]

(20 marks)

[b]   The detailed location of the sealant application was shown in Figure 3[b] which consists of two parts. The sealants must be applied around of both parts. Sketch the motion of Kuka Robot to complete the process efficiently. Also, include the related point in your sketch.

(30 marks)

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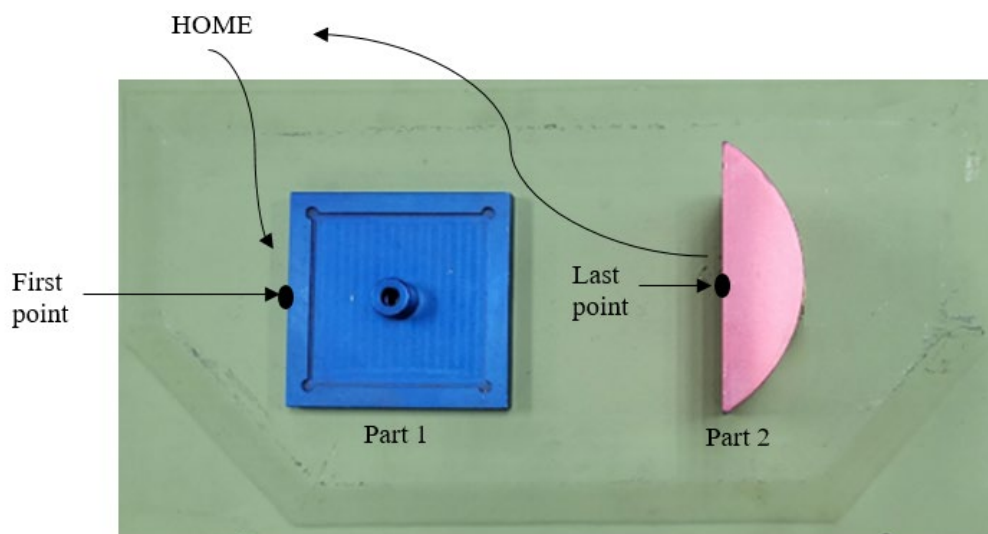

Figure 3[b]

(50 marks)

…5/-

4.   [a]   (i)   State the type of robot arm in Figure 4[a] and draw its workspace.
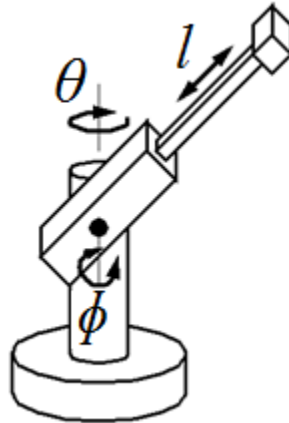

Figure 4[a]

(20 marks)

(ii)   From Figure 4[a], by using inverse kinematics, translate all the Cartesian-coordinates system's axes to the robot's own set of coordinates. Given the current position of the end effector is (150 mm, 245 mm, 100 mm).

(40 marks)

[b]   (i)   Assign a coordinate frame of the links shown in Figure 4[b], using right hand rule. Create the D-H link parameters table.
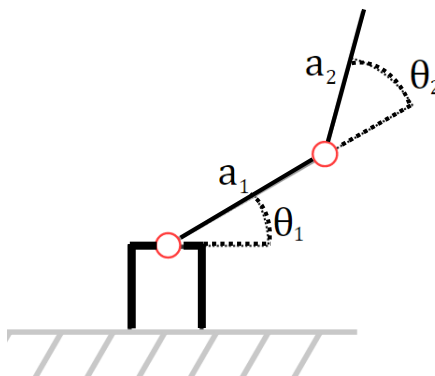

Figure 4[b]

(10 marks)

(ii)   Calculate the homogeneous transformation matrices T_{i-1}^{i} by substituting the link parameters from D-H table created in 4[b](i). Determine the overall transformation from the base of the link to its end. Given the homogeneous transformation matrices T_{i-1}^{i}:

$$T_{i-1}^{i} = \begin{bmatrix} C\theta_i & -C\beta_i S\theta_i & S\beta_i S\theta_i & a_i C\theta_i \\ S\theta_i & C\beta_i C\theta_i & -S\beta_i C\theta_i & a_i S\theta_i \\ 0 & S\beta_i & C\beta_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(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. How can industry 4.0 benefit to company in terms of costs, complexity, and productivity?

(30 marks)

[b]   Figure 5[c] shows the completed automated systems for packaging a bottle into the box using a robot arm. Based on your knowledge, list down five components that are necessary to use for assembly in this automation.
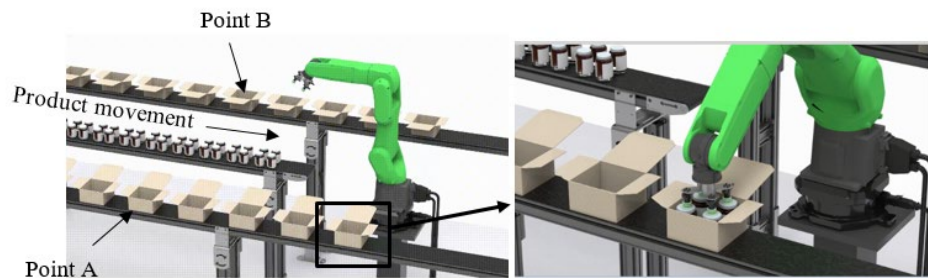

Figure 5[c]

(20 marks)

[c]   Develop a program of the Kuka robot for sorting the bottles from the conveyor to Point A and Point B as Figure 5[c]. The program must consist of execution control, subprograms, and functions to ensure that the proses is completely running.

(50 marks)

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